From Spanners to Suits

The Pursuit of a Management Methodology for Complex Integrated Solutions in the Aerospace Sustainment Context

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Executive Summary & Acknowledgements

Executive Summary

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CHAPTER 1

The Quest for a Management Methodology

1.0 6.2 billion reasons to think

1.0.1 A cautionary tale

It became a $6.2 billion management bungle.

Conceived as a masterstroke to thrust Microsoft into the online fore and become Google's equal, the 2007 purchase of online advertising network *aQuantive* instead became a quagmire that led to its first ever quarterly loss[1][1].

It wasn't because aQuantive was an inferior firm; in fact, it was quite the opposite. Before acquisition, it employed over 2000 people and was generating rapidly increasing profits and revenues (itself in the hundreds-of-millions before Microsoft's purchase). Its portfolio of online advertising technology and services was market leading.

So, what happened?

1.0.2 'Willy Wonka and the Vegetable Garden'

In short, it was a "culture clash."

As one insider described it, "It became increasingly difficult to combine the engineering-centric culture of Microsoft with the advertising-centric mindset of aQuantive." Whereas aQuantive's culture was agile and high-paced, Microsoft subjected it to its own more conventional way of doing business. aQuantive's approach was tailored to the advertising world, with high frequency product releases and constant customer contact; Microsoft's was driven by the long product cycles of Windows – a product which "dominated" the corporation's way of thinking.

[1] Microsoft formally wrote-off $6.2billion from the acquisition in June 2012, leading to a net loss of $492million for the quarter. aQuantive was purchased for $6.3billion.

This engineering-centric management approach of Microsoft soon curbed aQuantive's focus. "No amount of explanation about ad revenue versus software revenue or Google's plan to make software free could refocus a Windows-obsessed culture. As far as online advertising was concerned, the more important and familiar task was building a better search algorithm. Period."

As one insider put it, the "The task of evangelizing the business of advertising — not software — was akin to asking Willy Wonka to grow vegetables."

With Microsoft's obsession on developing a better search algorithm, key aQuantive staff left. The original portfolio of market-leading products and services dwindled, and were eventually subsumed into Microsoft's existing advertising unit, "shells of what they [once] were".

But what has this got to do with Complex Integrated Solutions and aerospace sustainment?

1.1 Setting the scene: the business of sustainment

The key spectacle of this study is traditional 'aircraft manufacturers' seeking to grow their business by entering the sustainment and maintenance market, positioning themselves not only as aircraft systems developers, but complete Integrated Solution providers. With more than 50% of an aircraft's lifecycle costs bound up in the in-service environment, and with acquisition cycles getting longer-and-longer (especially for the military), finding alternate sources of revenue has become a key pursuit of such aerospace and defence conglomerates. How could company Directors be responsible to their shareholders by neglecting a market that has the potential to double their revenues?

This is a corporate strategy referred to as "growth adjacent to the core"; in other words, pursuing business opportunities that have not traditionally been the 'knitting' of the corporation, but involve similar capabilities to their core business, and likely involve existing customers. Providing maintenance services, warranty programs, training solutions and even providing capability/operational services, such as operating a UAV on behalf of a customer, are some examples of this strategy.

Major business model innovations, too, such as performance-based contracting, where customers buy performance, rather than activity, have also fuelled this pursuit. Providing a fleet-wide Integrated Solution for an Air Force or airline customer where they pay a fixed fee for guaranteed availability and turn-around performance can be an attractive proposition for both parties. The outsourcing of risk is attractive for operator executives, and the prospect of fixed, long-term income is attractive for aerospace executives (along with the prospect of lowering costs over the life of the program boosting profits).

However, the realm of providing a fleet-wide aircraft availability service truly remains one of the higher risk, logistically intensive, infrastructure-heavy and workload-intensive business endeavours. Many firms offer such availability packages on subsystems and other inputs to the flying business, but few provide a whole-of-aircraft, fleet-based availability solution. There are many moving parts, many opportunities to lose significant amounts of money, and many relationships that need maintaining. But there is also the prospect of making a lot of money.

1.2 But what's the problem?

1.2.1 Finding a management methodology

The tale of Microsoft's bungling of a prized outfit serves as an admonition to firms who seek to seek growth adjacent to the core. Just because there might be similarities and commonalities between two types of business activities, doesn't mean that the management approach for one is right for the other. The very approach that had made the Window's platform successful had led to the downfall of the online-advertising business, despite a strong commonality of business activity (namely, information technology and programming). This phenomenon, managing a business according to its unique nuances, is referred to in this study as a "management methodology" – a management logic and approach to managing a business activity type according to its nature.

This study starts on this key predication:

> That aerospace & defence firms have strong management methodologies around their existing capabilities, such as design and manufacturing, yet there exists no clear, published management thought on how to manage a sustainment/support-focused Complex Integrated Solution.

As revealed through this study, there's some research into the business strategy aspects of Solutions in the aerospace & defence sector, including means of transforming such firms from pure manufacturer into service and solution providers. However, there exists a real dearth of insights that empower practitioners and executives to conceptualise and manage such complex service programs properly.

In particular, this study cautions against 'default thinking' – taking existing reasoning used for development and production efforts, and applying it to an inherently different type of business activity, one that's better understood from a *service*-centric thinking pattern, and not a *product*-centric one.

1.2.2 Understanding engineering in the sustainment context

Another complicating factor is that this business activity type is not just execution focused – that is, implementing according to a well-defined formula. *Complex Integrated Solutions*, a term used by this study to infer that these service programs involve multifaceted and complicated elements, take on a life of their own. They require higher-order levels of thinking in composing and executing a work program that meets a provider's obligations (and a customer's expectations – something discussed more in Chapter 23).

Practically speaking, this means that these service programs require the presence of a professional engineering force. However, given that many definitions of engineering are highly product-centric, what does it mean to be an engineering outfit in a highly service-focused environment?

It's an important question, as it goes right to the heart of such firms' capability. Engineering is the 'core DNA' of much, if not all, of such firms' activities, and readily forms the management ethos throughout the firm. Engineers tend to hold a power base in such firms through the sheer dominance and size of the engineering workforce. Thus, their presence readily drives much of the culture and ethos of how the firm pursues and executes its business opportunities.

1.2.3 Why two fronts?

These two seemingly split pursuits stem from a key strategic thought: that Engineering is an essential organ of a Complex Integrated Solution, even if its role is not always clear. Complex Integrated Solutions, and the Engineering Function that supports such a solution, need a common management system-of-thought/set of organising principles if they're to provide value. While Solutions are not wholly composed of professional Engineering outfits, understanding the unique role that Engineering can play is instructive for Solutions whose complexity requires an engineering presence.

1.2.4 Is it that big a deal?

This is not a study about whether there have been management failings of Complex Integrated Solutions (especially on the same level as the Microsoft example). Rather, this 'problem' is an assumption, one that is verified by:

- Observations that are taken from the case studies presented in this study
- Observations that are taken from existing literature about aerospace Integrated Solutions
- A lack of much quality management thought in this space.

1.3 This study's quest

So what does this study seek to uncover and achieve?

In short, it's about stimulating and prompting practitioners, managers and executives to construct their own deeper, richer mental models about how Complex Integrated Solutions exist and function, and to help them reconsider their existing understanding that might be causing conceptual blindspots that might lead them to mismanage such service programs.

Built into this rationale are three other objectives:

- 'Thingifying' Complex Integrated Solutions as a legitimate business activity typology that requires its own, well-considered management methodology
- Making Engineering in the in-service environment a normative endeavour, rather than an outlier
- Reposition the reader from understanding engineering and technical management matters from being about their technical tradecraft ('Spanners'), to an important organ of meeting customers' business needs ('Suits').

1.3.1 Key questions

As such, this study focuses on two central lines of inquiry:

- What are some fundamental properties of Complex Integrated Solutions that would help fashion a more precise management methodology for it?
- What is a new archetype for the Embedded Engineering Function for aerospace Complex Integrated Solutions (particularly those involving managing a fleet)?

The core takeaways from this study, however, are not a comprehensive management methodology for Complex Integrated Solutions. Rather, they're insights that help form the core reasoning for such a business activity typology, something built on more in Chapter 5.

1.4 A journey of discovery

This study seeks to answer these questions in a somewhat indirect manner with a more explorative approach. Instead of using management surveys or highly structured interviews of professionals, it instead delves deep into two case studies and lets the narratives speak for themselves.

Case studies are useful ways of examining a phenomenon in their context without imposing too much default thinking or interpretation onto the situation. While this study does ultimately seek to draw out common threads and concepts that are useful for readers to consider, the reader is also subjected to the case study material before these ideas are presented, giving them the opportunity to build their own ideas, and then being challenged by this study's insights.

This study is unreservedly focused on examining ways of delivering sustainment programs in an integrated fashion. As such, this report looks at two organisations who engage in delivering a business-orientated solution to a flying business. One is external to that flying business by a major Defence contractor; one is a key business unit within an airline. Both, however, discuss how they grappled with finding a more suitable form for both the organisational unit charged with delivering a Solution, but also the role that engineering has to play in that endeavour.

While this study is crafted using these experiences, information, and insights, it also draws on ideas and research findings from other case studies in a whole raft of different industries – rail, telecommunications infrastructure, building management, oil, and nuclear.

1.5 An important starting point

While much of this study seeks to be self-evident, there are some fundamental assumptions that are 'fixed' that permit this study to progress without getting too caught up on certain foundational points. There are seven key assumptions that underpin this study:

1. That innovative business models, such as performance-based contracts, will continue to be used in the delivery of sustainment services, and that manufacturing firms will be among the key providers of such services.
2. That aircraft and defence firms (as well as other sustainment providers) will tend to adopt default, product-centric reasoning when thinking and working on sustainment or service programs. Some firms might be quite meta-cognitively aware (i.e., think about their thinking); others might 'know no other way.'
3. That product-centric approaches and reasoning structures for sustainment-focused Complex Integrated Solutions are not sufficient to develop mental models and management methodologies to capture the full envelope of nuances and expectations that arise amid a sustainment-driven Solution.

4. That traditional concepts and definitions of engineering are not sufficient to capture the very real work and value that professional engineers bring to an in-service and sustainment environment.
5. That the proposed definition suite in this study, where engineering is seen as 'contriving a preferred state,' is a more suitable and workable definition.
6. That conventional Embedded Engineering Function (EEF) archetypes are under-developed and would benefit from fresh thinking.
7. That the concept of a *management methodology* is a useful term to explain the core 'product' of this study, even though it's not a term found in any leading published material.

It's also worthwhile noting that this study does use some terminology 'shortcuts' at times, in particular, the use of the word "Solutions" in place of sustainment-focused Complex Integrated Solutions. It's important to point this out for two reasons:

- This study asserts later on that there are Integrated Solutions, and there are *Complex* Integrated Solutions
- Solutions in this context are referred to as sustainment and support-focused ones, and not necessarily more involved capability/flight operations ones, or training programs (although the principles discussed might be applicable).

1.6 The travellers' experience

Before plotting this study's journey, it's important to pause and consider three important questions:

- Who is this study for?
- What's the nature of the study?
- Does it go in an expected direction?

1.6.1 Who is it for?

While the primary audience for this study is managers (both business-line and engineering) and executives in aerospace & defence firms, other practitioners in the sustainment space, too, will find some facets of this study thought-provoking. The Chapters on the true essence of engineering, and on airworthiness management, in particular, will have broader application.

1.6.2 Style of this study

Readers will find that this study is not a set of quick-fire insights that can be applied directly to an existing sustainment operation, and merely contributes to the periphery of existing thought. Instead, this study invites the reader upon a journey that encourages a substantial rethink to this space. Where it's very easy to skim the surface, this study seeks to go beyond the scene and lets the case studies drive the thinking, rather than default thinking.

As such, readers will notice a few distinct characteristics of this study:

- It will feel like a monastery experience. It's extensive, long and deep.

- The concepts are not always orthodox, and may at times be frustrating.
- Much of this study won't feel materially connected to the pursuit of a more refined management methodology. Alas, it's building a new core reasoning for it.
- It has a peculiar lack of familiar 'jargon.' To pursue greater accuracy of thought, this study has sought to use different language to focus on and enrichen the meaning behind concepts that can be taken for granted.

This 'slow-cooked' approach may be daunting; however, it will help conquer default thinking and will promote higher order thinking and reflection so that the reader can develop a deeper and richer understanding of the sustainment and Solutions domain.

1.6.3 Preventing disappointment

When broaching this Sustainment Solutions field, readers can adopt certain expectations or conceptualisations about what a study might be seeking to address. So, what *isn't* this study about? The following makes for an inexhaustible list.

What makes it a little more tantalising (yet perhaps disappointing) is that many of these matters are either briefly touched on in this study, or will be enhanced from the insights established in this study. Nonetheless, it's important to note that this study does not seek to provide any solid contribution on:

- The viability of the performance-based business model for contracting firms
- Policy matters, such as whether performance-based contracting and outsourcing methods are value-for-money or pose concerns for sovereignty of warfighter assets (e.g., a private contractor having such a critical part to play in delivering front-line capability)
- Modeling of contract parameters for cost estimation
- Customer relationship management techniques, including feedback & satisfaction loop design
- The design of a Solution-driven business management system, such as program review schedules or management structures (although much of this study's insights will help generate such a system)
- A toolbox of management techniques useful in the Solutions context
- A Solution design methodology based on service design concepts (but, again, this study can contribute to this endeavour)
- Risk management and mitigation strategies for Solution providers (an important endeavour given how much risk is transferred in such contracts)
- Data analytics and decision support systems for sustainment programs
- A management 'how-to' guidebook for operating Sustainment Solutions
- A practitioner handbook on running sustainment programs
- A complete concept-by-concept takedown of existing product-centric thought
- A transformation strategy for 'traditional' manufacturing firms to become sophisticated Solution providers (however, again, insights from this study will help with this broader endeavour).

There's also one other thing this study is not: a full, encompassing and complete management methodology for the sustainment-focused Complex Integrated Solution typology. It's a contributor to it, with other research, insights, and perspectives necessary to advance and grow the reasoning nucleus.

Nonetheless, they're insights that should, in their own right, stimulate deeper patterns of thought in the mind of the practitioner, manager, and executive.

1.7 Plotting the expedition ahead

1.7.1 Core threads

Readers will notice that presence of some motifs and key themes throughout this study's journey. They are key conceptual landmarks that appear in several locations and act as threads that pull this study together. They're concepts developed in far more detail as this study pressed on; however, they are listed up front to equip the reader with a set of 'waypoints' throughout this journey. These core themes include:

- **The Embedded Engineering Function:** The engineering unit led by professional engineers that is attached to an operator of a fleet to control the configuration of that fleet.
- **The Complex Integrated Solution:** the type of Complex Service Program that's built around some customer endeavour or need by a Solution Integrator/provider
- **Service-Centric Thinking:** A 'dominant worldview' or mental lens that causes individuals and collective groups to perceive, think and respond to certain phenomena. Service-centric thought is at the heart of this study and is often juxtaposed with product-centric thinking, itself posed in this study as an inferior thinking style in Sustainment and Solution contexts.
- **Sustainment & support:** the activity of sustaining an asset, and providing the necessary support to keep a system and customer operational. This is also referred to as *Fleet Management* where the context is more business focused.
- **Business-versus-technical discipline:** Providing maintenance and sustainment efforts both involve technical and scientific matters, as well as business matters. 'Doing maintenance' is technical; 'providing maintenance' is a business proposition. At the heart of this study is a focus on delivering against business needs, not just technical ones.
- **Engineering is more than building bridges:** That engineering is more than design and construction; it has a sometimes-undefinable effervescence that's of value in some many more situations and modes.
- **Cogency:** The end-state this study seeks to produce in readers – that is, a heightened sense of understanding and clarity about this space
- **Complex Service Programs:** A means of classifying complicated and multifaceted industrial service programs. It's a term seemingly used instead of Complex Integrated Solution; however, a CIS is one such example of this classification.

1.7.2 Study structure

So, how is this study structured?

It's divided up into six parts, plus this introduction:

- **Part 1 – Through the Looking Glass:** Borrowing from *Alice in Wonderland*, there's more to the world of Sustainment, engineering, Solutions and management that first meets the eye. This part explores the Sustainment marketplace, some of the language that's used in it, and at the makeup of Solution providers. It also looks closer at the notion of management methodology, plus at a philosophical question: what is engineering?

- **Part 2 – The Conceptual Building Blocks:** Much of this study is built upon the shoulders of existing thought and ideas. In particular, the concept of service-centric thinking, and the unique properties of Integrated Solutions are more closely examined. The enabling disciplines, such as logistics and sustainment engineering are reviewed, and the Part concludes by looking at a topic often missed from discussion about sustainment and Solutions – safety management in hazardous industries.
- **Part 3 – Learning from Real Life Cases:** Central to this study's investigation is a close examination of two major case studies of aircraft sustainment Solutions. However, they're not merely snapshots of business-as-usual operations. Rather, each case study documents not only the 'usual' operations, but significant dilemmas and challenges faced by each Solution, particularly as they grappled with what it meant to be a Solution, and also what it meant for the professional engineering outfit associated with that operation. These deliberations present a unique insider perspective on the thinking and critical factors that affect such providers and the approach they took to managing their Solution offerings. This part ends with a chapter reflecting on key lessons that this study took from both cases.
- **Part 4 – Business Not-As-Usual:** New ideas and conceptualisations are presented to help build a stronger core-reasoning around managing Solutions, based on lessons from the case studies and existing research.
- **Part 5 – A Search for a New Embedded Engineering Function Archetype:** This study takes it down a level, and uses the insights generated in Part 4 to find a more sophisticated and aligned concept of the Embedded Engineering Function in the Solutions context. However, they're findings and ideas that have implications beyond the Solutions context.
- **Part 6 – A New Flightplan:** Where does this study arrive? And what can the reader take away from this study?

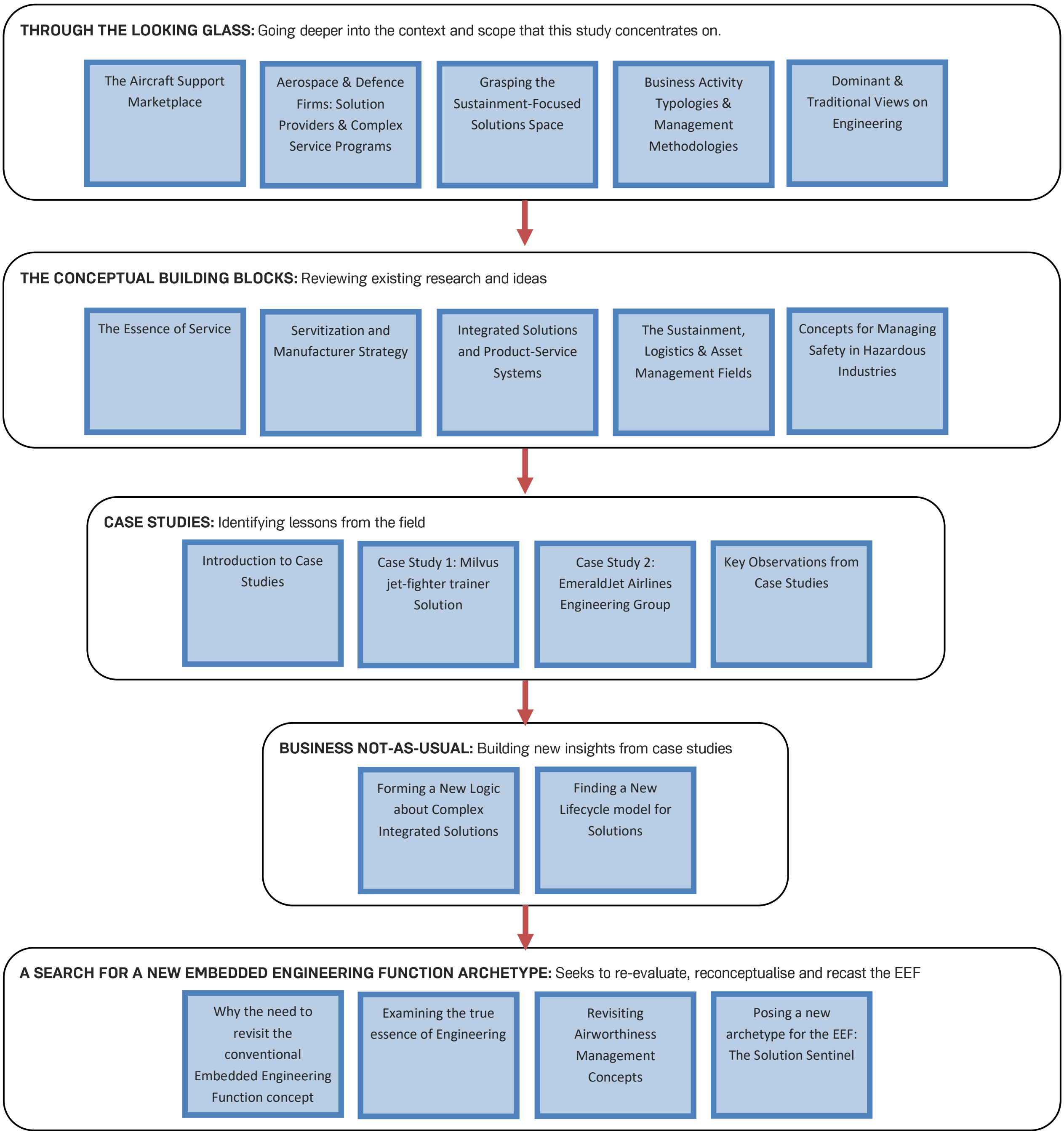

Figure 1: Structure of the study

1.8 A pre-departure thought

The central concept of pursuing a management methodology is involved and potentially obscure. Thus it's more fully expanded upon in Chapter 5. However, as the reader works through this study, it's worthwhile keeping in mind the logic posed in Figure 2.

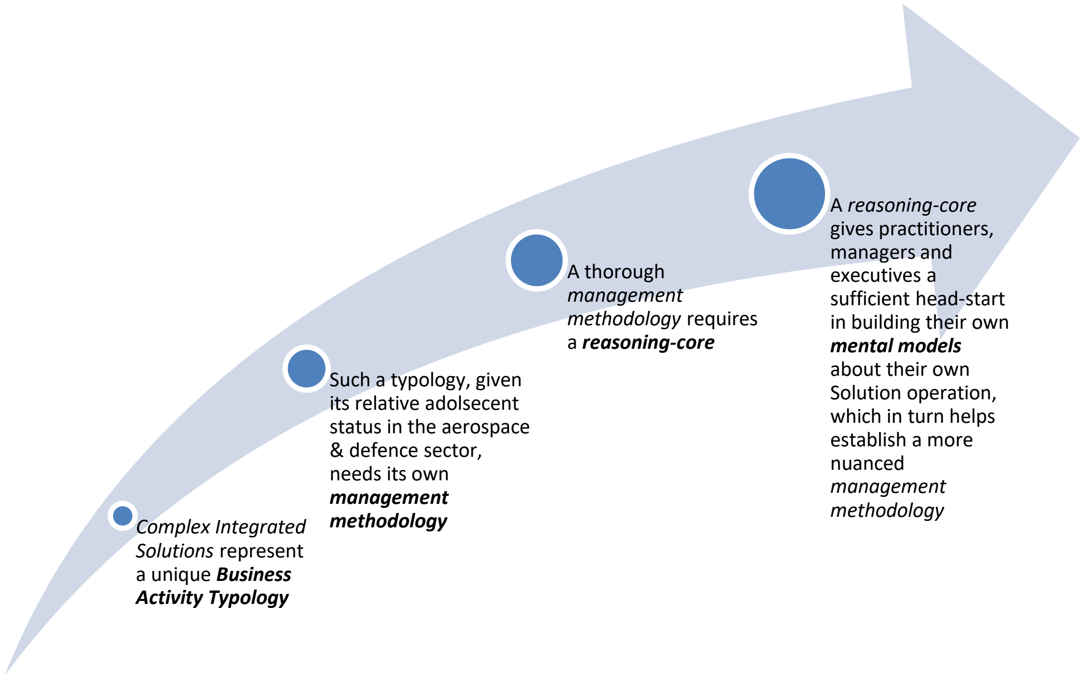

Figure 2: Core logic of this study

While this study presents several useful ideas and conceptualisations of the Sustainment-focused Solutions context, there's value to be gained from the reader reflecting on their own ideas and ruminations that arise as they work through this study. This includes harnessing the likely moments of chagrin over the next 29 chapters to think deeper. Such an invitation strikes at the raison d'etre of this study, and reflects a compelling sentiment attributed to Albert Einstein:

> "The world as we have created it is a process of our thinking. It cannot be changed without changing our thinking." [2]

Welcome aboard this quest *From Spanners to Suits*.

Part I

Through the looking glass

CHAPTER 2

Sustaining Opportunity

The Aircraft Support Marketplace

2.0 Trying to take a snapshot

So what is this through-life Sustainment marketplace where manufacturers are seeking to sell Solutions?

Alas, it's a bit like seeking to take a family photo with highly energetic children that won't sit still. It's an intricate sector, awash with terminology, brand-names, and business models that depart from the traditional order of aircraft manufacturers selling aircraft systems to operators, and then having a limited support role thereafter (namely parts and safety-related technical information transmission).

Some of the industry terminology, too, isn't as precise as it might be, with innocuous terms pointing to concepts that do have different meanings. It's also a space that is constantly being reshaped by political, economic and market forces.

Thus, before seeking to craft insights for a management methodology for sustainment-focused Solutions, it's important to first get a handle on the multifaceted and somewhat unstructured nature of the aircraft sustainment and support marketplace.

This chapter is not a full and complete survey of the sustainment landscape. Capturing and putting order to the full spectrum of the support and sustainment space is potentially a PhD exercise in its own right, not to mention focusing in on the drivers and shapers of this dynamic space. However, this chapter does offer the following:

- A sense of the size of the marketplace
- A taste of real-life contracts and programs that are similar to the business activity typology to be examined in this study
- An outlay of the variety of contracts and programs in this space
- Some definitions and clarifications of key terms used in this space
- A summary of Defence industrial policy settings in three important western defence markets
- An overview of some of the weaknesses and failures observed with manufacture endeavours into this space.

It's not the aim of this study to help articulate a new order for this marketplace; however, the next few chapters do introduce some frameworks to help readers navigate through some of the complexity. Instead, this chapter is an introductory primer to a lucrative marketplace.

2.1 There's money to be made

So why have manufacturers decided to enter a space that has traditionally either been the domain of the operators themselves, or sometimes that of independent service providers? Performing in-service support activities, such as maintenance, logistics, training, and upgrades has taken the eye of many players in the Aerospace and Defence market due to its size.

Quantifying the exact size of the market is not straight forward, with an array of aircraft, customers, markets and providers meaning precise values for whole-of-airframe support costs are difficult to lay out. However, Table 1 does give an indicative size of the marketplace for whole-of-aircraft support capacity.

Table 1: Various estimates and projections of MRO demand as presented by various consulting firms

Market Segment	Then Estimate (Annual)	Future Projection (Annual)	Scope	Year	Source
Global (Western) Military Aircraft	$60.7B USD	$65B by 2018 (despite 'shrinking fleet')	MRO Spend (Including field maintenance, and airframe, component and engine overhaul)	2008	Aerostrategy [3]
US Department of Defense "Product Support"	$132B USD		'Product support' or 'system sustainment' of all land, sea, airborne and space-borne systems. It includes maintenance, materiel management, distribution, training, engineering management and support	2009	US DoD [4]
Global Aerospace MRO market worth	$135B USD		All facets of global aviation, including military, air transport, business & general aviation	2015	ICF International [5]
Air Transport MRO Demand	$64.3B USD [2015]	$96B by 2025		2015	ICF International [5]
Air Transport MRO Market (100+ seat aircraft)	$53B USD [2016]	$132B USD by 2035	MRO excluding upgrade services	2016	Airbus [6]

These might be impressive numbers; however, what makes them stand out even further is the estimated annual spend on new systems. ICF International [5], for example, estimated back in 2015 that the value of all aircraft production – including military fixed and rotary wing, civil rotary, air transport and business/General Aviation – in that year at $180.3B USD. With global MRO spend estimated at $135.1B USD, the one-off 'value capture' of aircraft sales only stood out from the MRO market by a third. Of greater note is that such spending projections are annual spends.

Thus, the desire to enter the maintenance/through-life support market is tempting for both independent service providers and system OEMs (including manufacturers). It's also helped when some estimates for the breakdown between acquisition and sustainment spend on a system is estimated anywhere between half, to one-fifth (i.e., acquisition spend makes up only one-half to one-fifth the total spend on a system through its lifetime)[7].

2.2 Stepping into the real world of sustainment contracts

While the figures might be appealing, just what kinds of contracts and programs are currently being executed in this space? Again, this sector is involved, with each operator and customer having their own set of needs which may involve the manufacturer, an independent service provider, or even their own internal response. However, reviewing some of the major sustainment contracts do give an idea of the business activity typology this study is examining.

2.2.1 F22 Performance-Based Logistics program

Lockheed Martin provides a performance-based Product Support Integrator service for the USAF on the F22 fleet known as Follow-on Agile Sustainment for the Raptor, or FASTeR [8-10].

It's a complex program that involves depot maintenance, a continual upgrade modification program, field service support, logistics, and other support activities for a fleet of 187 aircraft. Added to the complexity is the highly advanced nature of the airframe which continually receives additional engineering work to enhance its capabilities, as well as the support to operators across five key USAF bases from Hawaii to Alaska to Virginia. The aircraft are also often deployed into overseas theatres.

Lockheed Martin manages the workload and is accountable for the outcomes generated by the FASTeR program. Curiously, this involves directing and managing maintenance activity performed by three Air Force air logistics complexes which LM partners with. The ALCs, whilst a government outfit, are contracted to perform the hands-on maintenance activity.

Whilst it's not clear from public domain information about availability and other performance targets imposed on the FASTeR program, there have been some major achievements. In 2013 alone, the program identified and delivered savings of some $20M USD. Also in 2013, it delivered a record 71.1% mission capable rate. This is against 40% in 2005 when the aircraft first entered service.

2.2.2 C-17 Globemaster Integrated Sustainment Program (GISP)

Boeing is contracted by the USAF to provide a unique PBL solution to support not only its own fleet of C17s, but also for the Air Forces of the United Kingdom, Australia, Canada, Qatar, the United Arab Emirates, and for the airlift capability of NATO. This is achieved by using a "virtual fleet" construct to pool and position spares, along with field service teams for each customer, whilst joining back into the one management program. [11, 12]

The program has helped to deliver high levels of aircraft availability, even in an environment of high operational tempo with overseas deployment of the aircraft. In addition, cost savings have been identified by Boeing, claiming that according to USAF data, over a three year period, the GISP was able to reduce support costs by about 16% whilst still maintaining an 85% C-17 fleet Mission Capable Rate average.

The program has gone through several changes, since its inception in 2003. The most recent iteration is a ten-year contract signed in 2011 where it was restructured to provide more of the 'hands-on' maintenance work to the USAF's organic maintenance capability (Air Logistics Complexes) to help the USAF comply with section 2464, title 10, United States Code.

2.2.3 Rolls Royce Power-by-the-Hour

Whilst performance based logistics-style programs may seem to be a new concept, the reality is Rolls Royce recently celebrated 50 years of offering its own version called Power-By-The-Hour (PBTH) [13]. Power-By-The-Hour, as the name suggests, refers to arrangements with customers who pay RR a per-flight-hour subscription fee, and in return, RR provides all the logistics and maintenance efforts required for the upkeep of that engine.

PBTH is the service trademark that belongs to RR, and was originally introduced in 1962 to support the Viper engine on the Hawker Siddeley 125 business jet. It has since extended to most of the engines in the RR stable, and is one of several customer support programs that it offers to a range of corporate, civilian and military customers. It has become a flagship concept for many in the performance-based logistics and through-life support space [14].

2.2.4 TyTAN – Typhoon Total Availability eNterprise

To support the relatively new Eurofighter Typhoon aircraft in RAF service, BAE Systems UK provides an availability-driven sustainment scheme.

The original contract was signed back in 2009, then called the Typhoon Availability Service. In 2016, the RAF signed with BAE Systems for the next phase of the program for ten years under the new banner of TyTAN or Typhoon Total Availability eNterprise [15].

BAE System's solution to the RAF supports and makes aircraft available at six key locations across the UK, Cyprus and the Falkland Islands. Its integrated nature sees BAE Systems act as a support integrator, combining under their direction efforts from engine and avionics providers to ensure a cost-effective scheme. It's estimated that the ten-year program will be worth £2.1bn to BAE Systems, but will yield £500m of savings over the program's life [16].

Of note is that BAE Systems sustain and support not only the aircraft; the company also runs the simulator training centres for the RAF's Typhoon fleet, as well as performing fleet operations planning, logistics and spares management, airworthiness control, and aircraft maintenance.

The scheme is also subject to operational demands that require company flexibility. For instance, the aircraft was used by the RAF for an immediate strike on Libya in 2011. After an RAF briefing on the operational requirement, BAE Systems' tempo matched that of the RAF to ensure sufficient fleet availability and systems serviceability for this sudden surge in demand [17].

2.2.5 Hercules Integrated Operations Support

To bring together many piecemeal support contracts into one, long-term and integrated support program, the UK MoD devised the Hercules Integrated Operations Support (HIOS) scheme to boost the availability of 2 models of the C130 Hercules in a cost effective manner [18]. It's been estimated that the integrated approach could save as much as £170 million of savings over the remaining life of the fleet compared to the traditional piecemeal approach.

The program represents a 24-year endeavour with fixed-price contracts locked in for 5-years at a time. It's estimated that between the original 2006 contract signature, and the withdrawal of the types, the HIOS scheme will represent a £1.52 billion program. It's devised as a major partnership between:

- The OEM Lockheed Martin (which includes product Design Authority and spare parts provisioning and management)
- Marshall Aerospace as the deeper maintenance service provider, as well as the service integrator and who 'leads partnership activities'
- Rolls Royce as the engine OEM to provide engine support and spares
- MoD Integrated Project Team to oversight the whole scheme
- RAF Lyneham as the forward (line) maintenance provider
- Other RAF/MoD units who place demands on the scheme, such as flying program tasking and capability development.

2.2.6 Boeing's Goldcare offering

Alongside the launch of Boeing's 787 aircraft, it introduced a service program called Goldcare. It was originally envisaged as a comprehensive flight-hour subscription service for 787 customers where airlines would contract Boeing to provide all maintenance, logistics and engineering activities necessary to deliver sufficient fleet availability to meet an airline's flying program. By 2012 the concept grew to cover other aircraft within the Boeing product stable.

However, the service offering changed, and by the time the 787 was being delivered to customers, revised the Goldcare concept to a portfolio of service options that airlines could opt for in a tailored approach[19]. It now includes three key forms:

- **Maintenance Execution:** the physical performance of maintenance tasks, much like any independent MRO provider
- **Engineering:** The provision of in-service engineering activity, including data management, reliability assessment, maintenance scheduling

- **Material Management:** Spare-parts sourcing and availability programs, delivered in a tailored, cost-effective manner
- **Goldcare Enterprise:** The complete integration of all the above aspects into an integrated solution for an airline designed to deliver fleet availability

The success of the Goldcare program is difficult to ascertain, with little specific publicly available data on customer uptake of the various aspects of the Goldcare offering, and by whom. However, Boeing claims that it has "substantially grown its GoldCare subscriptions since 2013, providing support for 60 customers and more than 2,200 airplanes." [20]

2.2.7 easyJet A319 maintenance

In August of 2005, a "landmark agreement for the aircraft maintenance industry" was signed between the independent European MRO provider SR Technics, and UK-based low-cost carrier easyJet. The ten-year deal was worth about $1 billion over the life of the contract, and saw SR Technics taking responsibility for the "full technical support" of easyJet's growing fleet of Airbus A319 aircraft[2][21].

Breaking away from traditional approach of outsourcing, the contract stipulated a delivery of outcomes, in the form of cost predictability, and aircraft availability. It also required a concentrated effort to see a reduction in maintenance costs associated with the A319 fleet (excluding the engine maintenance costs) of at least 25% (or $18million USD) over the ten year contract.

The contract provided SR Technics with the freedom to make decisions the way they felt best, under a concept EasyJet & SR Technics referred to as the "intelligent" supplier. Such a supplier (or its networks) would have an "accumulated experience and wealth of data on aircraft, engine and component support to produce a maintenance program where the central theme is the constant driving down of maintenance man-hours".

The objective of such a move was to increase aircraft availability by reducing the turnaround time of aircraft undergoing maintenance visits. Cargolux finds that "what is important to us is the downtime – that's where the biggest money is [22]." Maintenance could be sent to a low-cost provider. However, whilst the labor rate is less, the turnaround times are higher (and thus the aircraft availability is less). When availability means the ability to make money, and downtime means forgone opportunities to make money, there are benefits in paying a higher price for faster maintenance times, which "intelligent suppliers" are capable of providing.

2.2.8 Other non-traditional business models

This chapter has so far focused on sustainment-focused and (generally) availability-driven service programs run by OEMs. However, this in-service environment is increasingly dominated by a range of business models and activities that depart from traditional logic. These include:

- **Adaptation of existing platforms into new systems:** Rather than developing entirely new platforms, a major disruption to the traditional lifecycle model is that existing platforms are being 'repurposed'. For example, the Boeing 737 into surveillance and maritime patrol roles (E-

[2] 54 aircraft at time of contract signature, and was estimated to reach a total of 120 by the end of 2007.

7 and P-8), the Airbus A330 into an in-flight refuelling asset (KC-45), and the Bombardier Global Express into a SIGNIT asset (the R1 Sentinel).

- **Selling of 'capability' rather than assets:** One stand-out example is that of Aerosonde who, rather than selling RPAS assets, instead sell customised sensor datasets based on devising and operating a mission using the Aerosonde platform, with a tailored instrumentation package for a client[3]. Everything from design, production, maintenance and operation is conducted by the company but devised in collaboration with the client.
- **Leasing-versus-owning:** the UK's Future Strategic Tanker Aircraft program sees a private consortium developing, owning and provisioning a fleet of in-flight refuelling tankers for the RAF. While the fleet is operated by the RAF, the private consortium can utilise the aircraft for other missions/customers when the RAF's operational tempo [23].
- **Major upgrade market:** Mid-life upgrades are not new phenomena; however, where there has been an 'unwritten' traditional logic that the OEM of the platform will be engaged to provide any major upgrade, this has been subtly changing. Two major examples of this have been recent USAF contracts awarded to Boeing to perform such major upgrades to Lockheed Martin designs – namely the F16 and C130 [24, 25].

Highlighting these differences is important for several reasons:

- Sustainment-focused services, solutions, and programs is not the only post-delivery offering by OEMs (and by other providers for that matter)
- The terminology used in this in-service environment can be mixed in its meaning (discussed shortly), and can sometimes infer the business models above
- The scope of delivery of such sustainment programs can vary (as also discussed shortly).

However, these business models are also highlighted for one other important reason: namely, to give a greater sense of the complexity in the aerospace industrial landscape, and that traditional lifecycle logic, such as the linear progression from design to operation, is not a true representation of the dynamics of this landscape.

2.3 Terminology bingo

What can make understanding this post-delivery world confusing is the myriad of terminology that, on the surface, seems to suggest similar concepts. Different stakeholders use different terminology to describe similar, albeit not always identical, concepts. Some are brand names, some are concepts espoused by customers (particularly Government/military), and some have emerged from professional practise. It's not unknown for these terms to be used instead of others, even though the concept that's been referred to changes (or is mixed with others) with the context.

This study predominately concerns itself with 'sustainment' or 'through-life' management. However, there is an abundance of other terms, too, including:

- 'capturing the aftermarket'
- 'going downstream'
- integrated solutions

[3] Based on a presentation to the Royal Aeronautical Society (Melbourne Branch) on Tuesday 15th June 2010

- sustainment solutions
- service and support
- Through Life Support/Management
- Through Life Capability Management
- Performance Based Logistics
- Power-By-The-Hour

However, these are loaded terms, potentially meaning one (or more) of several concepts.

Table 2: Common terminology used in the sustainment environment

Term	Commonly Used Where	Formal Definition	Further Espoused
Performance-based logistics (PBL)	Extensively in the United States and partly in Australia	PBL is synonymous with performance-based life cycle product support, where outcomes are acquired through performance-based arrangements that deliver Warfighter requirements and incentivize product support providers to reduce costs through innovation. These arrangements are contracts with industry or intragovernmental agreements. [26]	A contracting mechanism whereby performance-based outcomes are required for full payment for services. This is done at three levels: System, Sub-System, and Component
Contracting for Availability	UK, sometimes Australia	Contracting for Availability (CfA) is a commercial process which seeks to sustain a system or capability at an agreed level of readiness, over an extended period, by building a partnering arrangement between the MoD and Industry [27]	Similar to PBL, but where the performance metric is system availability
Through-Life Support	Primarily Australia	"A whole-of-life management methodology that takes an integrated approach to all aspects of supportability and readiness of a capability or materiel system." [28]	
Through-Life Management	UK	Through Life Management (TLM) is the philosophy that brings together the behaviours, systems, processes and tools to deliver and manage projects through the acquisition lifecycle. [29]	
Performance-Based Contracting	Primarily Australia	A product support strategy utilised by Program Managers (PM) to achieve measurable war-fighter selected performance Outcomes for a weapon system or subsystem. PBC utilises performance Outcomes such as availability, reliability, maintainability, supportability and total ownership cost. The primary means used to accomplish this end are incentivised, long-term performance-based contracts with specific and quantifiable levels of operational performance as defined by the user. [30]	Also known as 'Outcomes-Based Contracting'
Product Support	Various (dominated by US)	The term "product support" means the package of support functions required to field and maintain the readiness and operational capability of major weapon systems, subsystems, and components, including all functions related to weapon system readiness. [31]	
Lifecycle Logistics	(generally used in the United States)	Life Cycle Logistics is defined as the planning, development, implementation, and management of a comprehensive, affordable, and effective systems support strategy. Lifecycle logistics encompasses the entire system's life cycle including acquisition (design, develop, test, produce and deploy), sustainment (operations and support), and disposal [32]	
Through-Life Capability Management	UK	The translation of requirements into an approved programme that delivers the required capabilities through-life, across the Defence Lines of Development. The terms Through Life Capability Management and Capability Management are interchangeable [27]	

2.3.1 Common terminology lacking commonality

To provide some clarity on the difference between the terms, many of these concepts invoke one or more of the following concepts.

2.3.1.1 The sustainment body of work

The 'what' of aircraft sustainment or support, including the existing and defined maintenance and logistics support disciplines and their application to the sustainment of a system. They are actions which must be performed by any entity (commercially outsourced, or internally provided) to make the aircraft flyable, airworthy and safe.

2.3.1.2 The level & length of commitment

Terms such as through-life management and lifecycle support point to some long-term commitment to a product, sometimes for 'whole-of-life.' This is to reflect a commitment to support or sustaining such an asset over the long-term. This is in contrast to some previous industry behaviours where product commitment was fairly short term. Authors such as [Sabbagh, Lele] suggest that the traditional manufacturing firm has a strong focus on designing and building products, but that providing a commitment to support them has not been seen as the core business of such a firm. In some instances, support is seen as a "necessary evil [33]" rather than a business opportunity. Using terms such as TLS can be used to infer a sense of standing by one's product line, even if it is no longer in production. This ethos can be expressed in a spectrum of ways, from simply maintaining a spare parts service, through to highly sophisticated and well-thought-out support services.

2.3.1.3 The sustainment entity

In other words, the 'who' of sustainment and support. Should the support of an aircraft fleet be conducted by the organisation that owns and/or flies the aircraft, or should it be outsourced to another party? Should leasing companies move up the value-chain and offer a 'flying commodity' (an aircraft ready to use without the need for any inherent support capabilities within the operator firm), rather than a capital asset class?

It's an important point, as not all performance-based regimes have to be outsourced. In fact, the DoD uses PBL arrangements between its constituent agencies, branches and operational units.

2.3.1.4 The entity's pledge

Should the support activity be provided as a time-and-materials arrangement, like a car mechanic where the customer simply pays for the labour and the parts used, or should it be delivered through an alternative contracting mechanism, such as performance-based logistics? This really relates to the terms of the commercial or performance offer, rather than the *what*-type activities.

2.3.1.5 The opportunity and innovation of support

Some support contracts are "piecemeal" (i.e., each task, such as a repair, is a separate contract, without any incentive to reduce the costs associated with that task); others are highly integrated. The opportunity of support relates to the strategic vision of support, whether it is seen as a cost, or an investment, a side-line business, or an opportunity for an entirely separate line of business. The opportunity of support also correlates to how value is perceived about support, as well as how comprehensive a support package may be. Is it viewed as another, 'normal' activity, or as potentially a radical, game-changer in the way that PBL has been touted by some participants (such as the US DoD).

2.3.2 Differences in scope

These multivariate definitions give rise to another critical distinction that must be drawn: the variety, scope, and depth of outcome that is sought by a sustainment customer. Some PBL programs merely acquire components on a performance basis (e.g., turnaround time in repair, or stock-on-shelf at any point in time). Some contracts dictate video hours over a target area[4] (and thus are more than sustainment-only programs).

The US DoD's Acquisition Guidebook thus illustrates some of increasing levels of depth and 'functional scope' that may be sought in a contract (see Figure 3). It ranges from the delivery of support elements, such as parts, to whole-of-system sustainment, right through to delivering an operational effect.

[4] See other non-traditional business models.

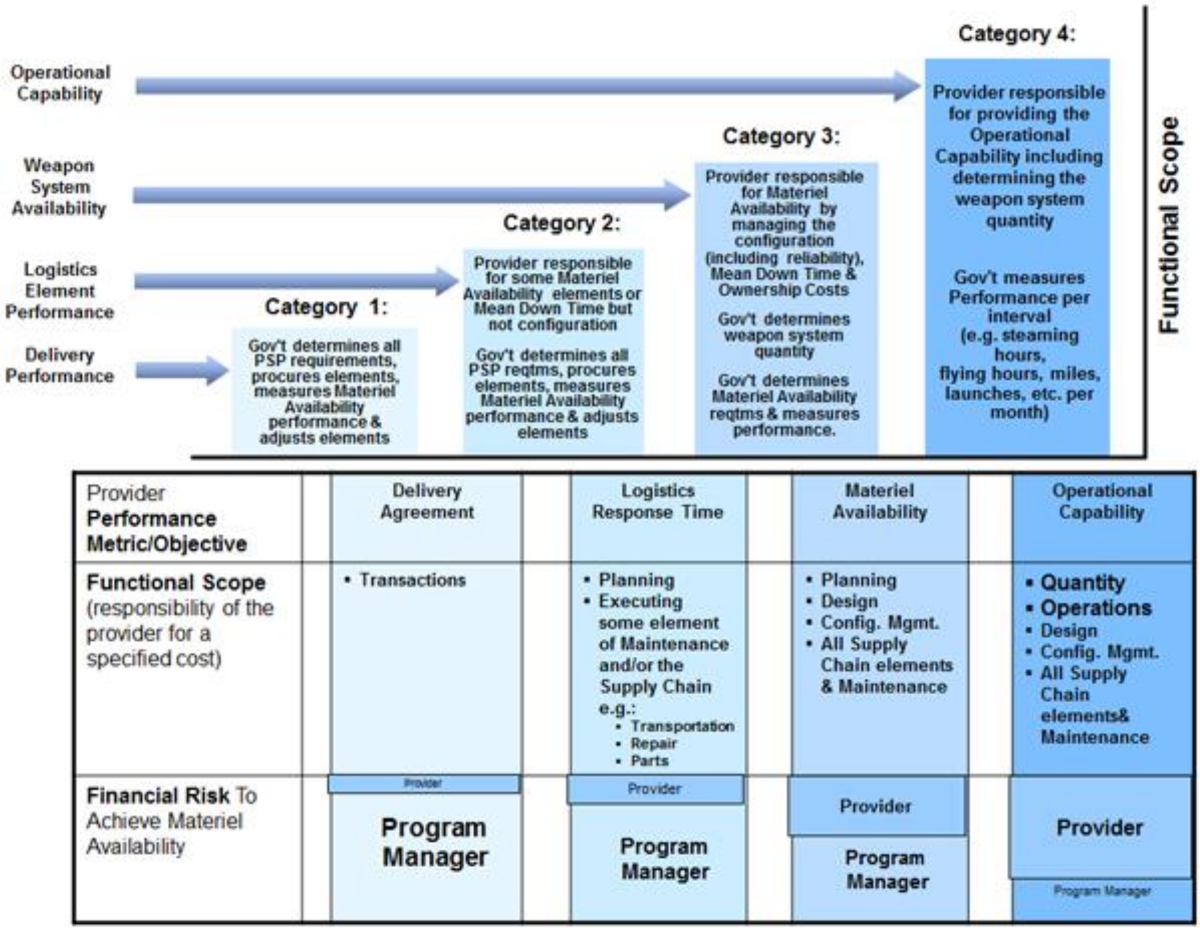

Figure 3: US DoD approach to Performance Based Logistics [34]

It's a framework not too dissimilar to one generated by the Australian DoD in its Aerospace Sector Strategic Plan of 2003 (see Figure 4). BAE Systems also generated such a framework in 2010 [35], identifying six types of "Readiness and Sustainment" solutions, namely:

- **Transactional:** Ad hoc support arrangements only (Type 0)
- **Component availability:** The delivery of components within a specified timeframe and cost (Type 1)
- **Materiel availability:** An agreement to deliver availability of designated sub-systems (or components) – incentivised to improve reliability and reduce in-service cost (Type 2)
- **Operational availability assurance:** Delivering systems or platform operational availability over a period, incentivised to reduce through life system/platform costs (Type 3)
- **Fleet availability/assurance:** Delivering the availability of a fleet (or portfolio) of systems and/or equipment over a period, again incentivised to reduce through life fleet costs (Type 4)
- **Force availability/assurance:** Delivering availability of a force or force element at a specified level of military effect over a period and including a successful mission outcome, also incentivised to reduce through life force/capability costs (Type 5)

Again, these distinctions illustrate that the in-service environment is a complex sector and that care is needed in describing exactly what type of 'sustainment solution' actually is.

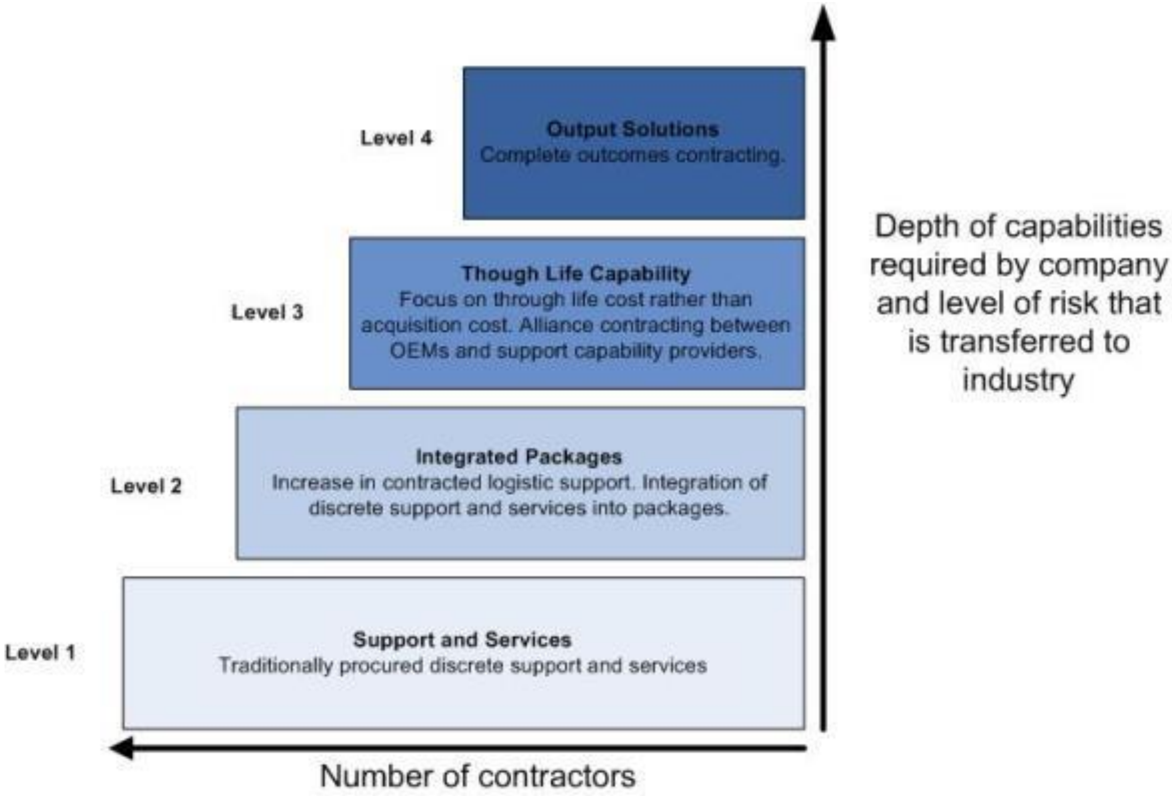

Figure 4: Systems and support capability framework in the Australian context [36]

2.4 Strategic policy and sustainment

The advance towards Performance-Based sustainment programs such as PBL and CfA does represent a departure from traditional sustainment practise, and is a development that is now increasingly recognised as part of Defence Department policy in various jurisdictions. Again, this study does not focus on this strategic policy arena in any great detail; other studies provide a more nuanced strategic assessment of this movement, including the trade-off between national sovereignty and a more efficient deployment of resources [37]. However, it's worthwhile quickly revisiting the various policy positions of the United States, the United Kingdom, and Australia – three countries who have shown quite a significant uptake in performance based sustainment concepts.

2.4.1 United States

The US DoD first introduced top-level policy concerning Performance Based Logistics back in 2001 with the Quadrennial Defence Review (QDR) by stating the "DoD will implement Performance-Based Logistics to compress the supply chain and improve readiness for major weapons systems and commodities [38]." It's a response to the QDR's observation that the DoD "maintains large inventories that could be substantially reduced by applying an array of supply chain practices", including that it "incurs significant overhead costs for functions that vendors could perform". Thus the belief that savings could be found by the "use of industrial partners responsible for life cycle support of a weapon system or commodity item".

This high-level policy from the QDR soon became institutionalised within the DoD in 2003 with the release of DoD Directive 5000.01, stating that system Program Managers "shall develop and implement performance-based logistics strategies that optimize total system availability while minimizing cost and logistics footprint [39]." This was reinforced with the publishing of an overhauled DoD acquisition framework in 2008 via DoD Instruction 5000.02, where PM's are required to "develop and implement an affordable and effective performance-based product support strategy" and "employ effective performance-based logistics (PBL) … in developing a system's product support arrangement [40]." However, this doesn't necessarily mean outsourcing to commercial providers, with government service providers also participating in performance-based regimes.

2.4.1.1 Acquisition & Sustainment Framework

The acquisition and sustainment framework set-out in DODI 5000.02 is the basis for a significant set of policies, handbooks, procedures and standards used across the US Defense enterprise. A significant component of this framework is that of the Program Manager who is accountable for the development, production, and sustainment of a system or platform for warfighter needs. However, the 5000.02 framework also establishes the role of the Product Support Manager (PSM). This PSM is responsible for ensuring the implementation and oversight of some sort of product support scheme that will deliver availability and readiness of the weapons system.

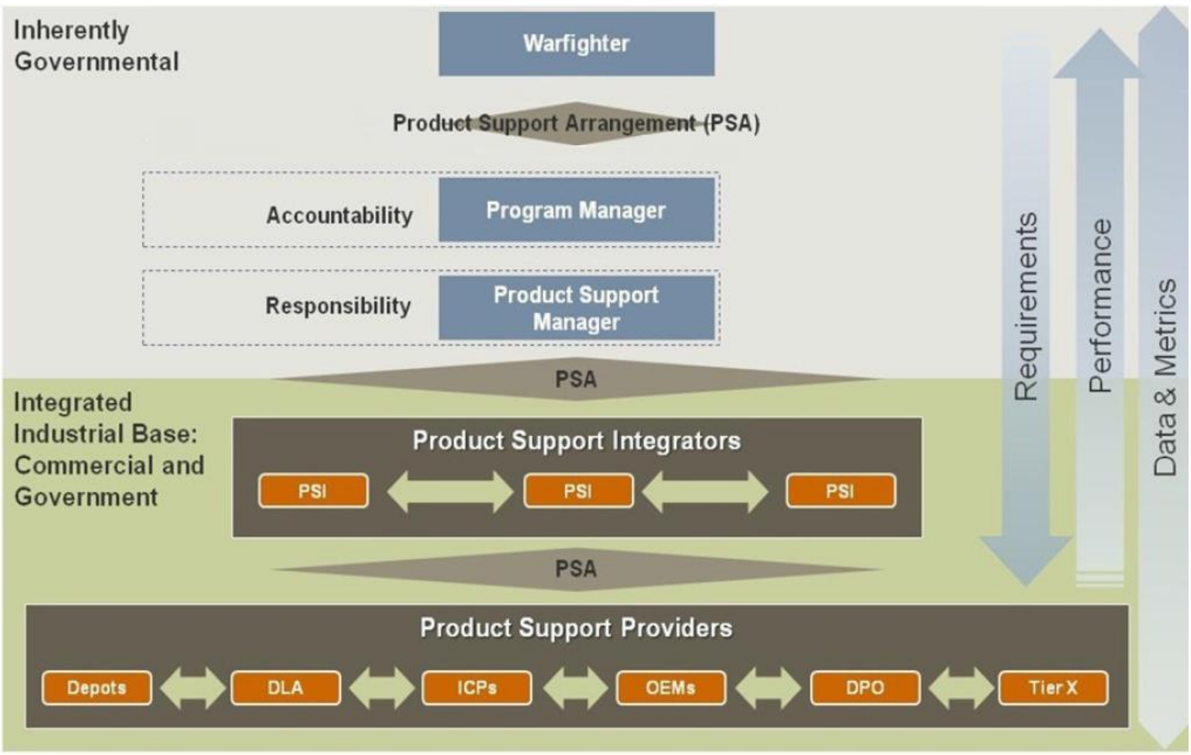

Figure 5: US DoD product support framework [41]

This framework also makes clear the distinct responsibilities for system support and sustainment. Responsibility is held by the government for architecting and ensuring effective support efforts.

However, the day-to-day efforts for coordinating and delivering product sustainment can fall with industry (or a government provider) as the Product Support Integrator. The Product Support Integrator then sources product support providers, whether it be themselves, other independent providers, and curiously, other government support agencies. This is discussed shortly.

The DoD policy does give Program Managers options in how they construct these product support strategies. Perhaps most importantly is the recognition that PBL strategies can be enacted is various ways, generally on three distinct levels:

- **Platform** or whole-of-system level, such as an entire aircraft type (and subsequent fleet)
- **Sub-system** level, such as engines or major avionic systems
- **Component** level, such as a set of pumps, LRUs, or actuators.

2.4.2 Australia

In the Australian context, performance-based contracting of sustainment services has been increasing with popularity. Whilst no top-level official policy exists, there exists several mid-level policy documents and handbooks, including the Australian Defence Aerospace Sector Plan (2003) that commits Defence to actively pursuing 'an Outcomes-based approach to contracting and contract management' in the aerospace systems space [36].

Additionlly, the Australian DoD's procurement agency publishes guidance in forming performance-based contracts, with the Performance-Based Contracting Handbook for its aerospace systems division. It espouses key principles to be adhered to in the development and execution of such contracts, including:

- Careful selection of metrics
- The expectation of year-on-year improvement of performance over the duration of a long-term contract
- Circumstances under which contract termination may be triggered
- Principles concerning contractor profits, including their relationship to risk exposure and levels of performance.

The Australian DoD's approach to performance-based contracts has been subject to an evolutionary approach, including an extensive discussion paper in 2010 to work with industry to find ways of better institutionalising PBC concepts into the way Defence does business [42]. Interestingly, it notes that "implementing a performance-based support agreement is one of the most difficult tasks in [the] DoD," and considers many of the detailed contract mechanisms to help ensure contractor performance.

It also considers the nature of the Australian Defence context, and the effect of PBC approaches. One such factor is self-reliance or self-sufficiency, and that Australia has unique requirements, given its long distance from major system OEMs. This includes the need for dependable in-country support programs to ensure its platforms are sustained and readied for deployment, especially in the scenario of having air-sea access to such OEMs being cut-off during a conflict [43].

2.4.3 United Kingdom

Contracting for Availability is the key term used within the UK Defence context to capture concepts of performance-based support and logistics.

As a contracting concept, it emerged from several reviews and deep internal thought about how best to structure the logistics and support architecture across the MoD. This included the design of the repair network, a reworked industrial strategy, support base rationalisation, the standing up of a new Defence acquisition and logistics agency (DE&S) and the improved inter-service sharing of resources. Much of this consideration was developed during the 2003 study *Streamlining End to End Air and Land Logistics* [44] which informed many facets of the MoD's policy, including its 2005 *Defence Industrial Strategy* [45].

Whilst the DIS does not mandate the use of CfA, it does recognise increased efforts across the MoD to adopt this approach and forms a significant aspect of the Strategy.

It's an approach which has yielded significant gains, according to the National Audit Office [46]. For example, the Tornado IPT reported to the NAO that its annual cost to sustain the RAF fleet was £601million in 2001-02, but after the major efforts of reorganisation and placing a large, longer-term sustainment contract with industry, had reduced its annual outlay to a staggering £258million by 2006-07. It must be added, however, that the NAO found that the MoD couldn't capture one clear cost of maintaining the fleet, with other agencies and units beyond the IPT engaged in ordering spares and procuring support services for the same fleet. Nonetheless, it does illustrate the power of a more integrated approach, with the placing of long-term contracts identified as a key saving, replacing traditional, short-term contracting arrangements.

2.5 Not all smooth flying

However, despite the official enthusiasm for performance-based approaches to sustainment and logistics, it's not all been smooth flying, nor has the concept been without its challenges or critics. Perhaps the most noticeable of these has been in the United States in the earlier days of the PBL epoch.

2.5.1 Government Accountability Office findings

The Government Accountability Office, responsible for monitoring the performance of Federal government programs and activities to ensure integrity and value for money, has a rolling program of evaluating major defence programs, including PBL. Over the span of a decade, it released four specific reports [47-50] of investigations into DOD PBL contracts, with several other reports also examining sustainment efforts on major platforms (most noticeably the F35).

The GAO's reports have focused on a few recurring themes:

- That the DoD needed to do more to prove the value-for-money claims of PBL programs
- The need to improve cost data quality and analysis techniques (the GAO had concerns regarding the source and quality of cost data to model and justify expenditure on PBL programs)
- Feeding off the above two points, the need for more sophisticated and well-argued Business Cases before committing to an outsourced PBL arrangement

- The need to improve contract development and design. This included the availability of technical data, the advantages of requiring 'open book accounting' (basically the DoD being able to look at (but not interfere with) a contractor's financials for a PBL program to ascertain true cost drivers), the design of contracts to optimise contractor behaviours (including competition to drive costs down, and suitable 'exit strategies' for poor performance), and the design of PBL metrics to reflect realistic operator needs.
- The importance of architecting sustainment programs to give the DoD what it truly needs, employing PBL contracts only when it's clearly cost effective (such as balancing control, or perhaps introducing PBL contracts at the subsystem level instead of at the platform level)

These findings are certainly not a death-knell for PBL. However, they do serve as reminders that even though the concept might be sound from a theoretical perspective, its value must be demonstrated in every case, and is not an automatic success factor. If the business case cannot show PBL approaches are more advantageous than more traditional approaches, then there is no point in pursuing it.

2.5.2 Quirks

PBL concepts are also a field that's not without its quirks. Despite the US Government's enthusiasm for PBL, legislation introduced by Congress in the 1980s does place a major constraint on its uptake: namely, Title 10 Section 2464. In short, no more than 50% of depot-level maintenance (heavy maintenance) spend may go to non-government outfits (primarily private industry).

This sets up a unique set of circumstances. The first is the prospect of program cancellations or rollbacks. The C17 PBL program was cancelled in 2010 (before its relaunch in 2011), more officially due to concerns the DoD was approaching that 50% threshold [51]. However, it was also rumoured (from informed sources) that the DoD/USAF had concerns with a lack of value-for-money in the existing contract [52]. It was felt Boeing merely operated as work package integrator that passed invoices for work by other vendors through to the DoD, and then adding a separate management fee, with little perceived value-add.

The second unique circumstance is a unique way some programs are working around this constraint: by contracting an industry partner to run the sustainment program, but in-turn have that industry partner contract a government maintenance facility to conduct the physical maintenance effort. Whilst the industry partner conducts the overall management of the sustainment program such as logistics, data analysis and publications management (a topic of this whole study), the considerable physical maintenance accomplishment effort is performed by a government outfit that is specifically set up as a 'service provider' to DoD operational units, or industry PBL programs.

2.6 So what?

This chapter highlights that aircraft sustainment and through-life support is not a one-size-fits-all concept and that it can take many forms. This is an important point to be understood when seeking to find a management methodology for sustainment-aligned Solutions – that the real world is chaotic and doesn't always conform to an expected order. This affects this study's quest for a management methodology, which is effectively trying to find an order for a particular style or typology of a business activity.

That business activity typology this study seeks to examine more closely is a sustainment-focused, availability-driven, and customer-centric Solution that is mostly aligned with the whole-of-system PBL concept. It's not the full operational capability model where the manufacturer performs the customer's mission; however, this study does look closely at two major examples of sustainment and support programs that are highly enmeshed with the customer's own operations.

This does raise a few important questions, however. Namely:

- Where does all this sustainment and service activity sit with the most likely of Solution providers – major Defence firms and aircraft manufacturers?
- Can these sustainment and in-service environment concepts be a little more refined, including zeroing-in on the terms to be used in this study?
- What is this 'management methodology' quest, anyway?

These are questions examined in more detail over the following chapters.

CHAPTER 3

Understanding the Solution Provider Context

Aircraft Manufacturers, Defence Firms and Solution Providers

3.0 Building a more nuanced view

The servitization narrative described in Chapter 8, where 'dirty, old, metal-bashing' manufacturers seek to branch out into the services space and entirely reinvent their businesses can sound slick but can be simplistic. In the aerospace context, this narrative would be expressed by "traditional aircraft manufacturers" – for example, 'companies that just design and build jets' – moving increasingly into the services world, including through delivering Complex Integrated Solutions.

However, to suggest that modern aircraft manufacturers can only be expressed this way – as more traditional, metal-bashing firms – is flawed. So too is the notion that it's just manufacturers who would be keen to enter the aerospace services world, including Complex Integrated Solutions. Hence, this chapter seeks to consider briefly:

- Who can provide CIS's
- Can such firms truly be considered 'purely manufacturer', anyway?

The second question isn't to be picky about definitions; rather, it's to better understand the context and the starting point of such firms in a stereotypical fashion. As such, its derivation is not strictly academically rigorous, but it does serve an enlightening purpose.

It's not even central to the pursuit of this study towards finding a management methodology for Solutions; however, it does help position and contextualise where such efforts sit.

3.1 Who can play in this space?

Examining this space in a practical fashion, there are four types of firms that are realistic contenders to be Complex Integrated Solution providers:

- **Major aerospace & defence conglomerates:** Firms that have a broad range of programs and offerings, and generally offer a major airborne platform of some sort. This includes Boeing, Airbus Group, Lockheed Martin, BAE Systems, Northrop Grumman, and Thales.
- **Significant aerospace & defence firms:** Not the behemoths such as the above conglomerates, but still major complex systems players, such as General Atomics & Raytheon. They possess an extensive portfolio of programs and offerings, although may be a bit more niche than the major conglomerates and may not have a major platform on offer (yet still have sufficient organisational resources to offer Complex Integrated Solutions).
- **Pure/Focused aircraft manufacturing firms:** Gulfstream Aerospace, Embraer, Bell Helicopter, Cessna[5], Bombardier
- **Independent Service Providers:** Firms who have little or no development engineering or manufacturing operations, but that are structured as pure service providers. This includes firms such as Babcock, Serco, SR Technics, Cambridge Aerospace and AAR Corp.

This study is more interested in generating insights for a CIS management methodology in light of manufacturers becoming Solution providers. However, it's remiss to exclude these independent service providers as well, because, in a sense, they're all starting to exhibit some similar characteristics – namely, Solution offerings are part of a portfolio of activities such firms may be structured to deliver. It's just that some firms have wider breadth (with increasing organisational complexity to go along with it) compared to others.

3.2 Aerospace & Defence firms contractors are no longer just manufacturers

All of today's major defence contractors have a strong aerospace pedigree, with most starting out as more traditional design-construct-support product manufacturers. With time, these firms have diversified their portfolios – adding maritime, land, electronic, space, and more recently cyber/information capabilities to their business.

Traditionally technology and engineering firms, these companies have evolved to an organisational form where they can no longer be just expressed as engineering businesses. Ultimately, they've become conglomerates that possess significant resources at their disposal, and can readily reconfigure their enterprise structure to meet demand where their customers require it.

To express this situation pictorially, they're a warehouse of capabilities, and as a company is well resourced to find money-earning opportunities to which they can, with relative speed, reconfigure and deploy these capabilities to capture these valuable opportunities. Because of this, they can respond to a wide range of customer needs, whether they have the capability in-house, or can use their existing resources (especially financial) to pull together a program unit from external parties to execute the program.

[5] Noting, of course, that Bell and Cessna are both part of the larger Textron Group.

3.2.1 The Defence industrial approach

It's important to reflect, also, on a slight nuance of programs who have a Defence or government customer – customers who tend to make up the lion's share of most of these firms. Such technology and platform programs are seldom self-funded or initiated, unlike commercial programs. Most of their work program stems from successful bids made to large government departments or agencies on a range of work contracts – everything from entire aircraft development and production programs, to small trade studies.

Making the sector attractive to such firms is the nature by which government customers tend to make payments – namely more on effort, and not just for product. This lowers the risk profile to the contracting firm, as even if a program is delayed, they are generally assured of continued funding to finish the contract. Of course, this is not always the case, and there is an increased uptake of contracting vehicles to put more risk back onto the contractor (performance-based contracting been one of the key methods).

With the scope of work and price generally locked in before commencing work, there are even some instances where the contractor is paid a certain amount even when a program is cancelled (this, of course, is generally done through legal action, but the contract at least gives the contractor some recourse should this happen).

3.2.2 Well resourced

Because of this more stable contractual situation, these firms enjoy profitable programs which endow them with useful resources that position them well to seek out new opportunities. This includes in the field of Complex Integrated Solutions. But what are these resources that these firms have? And what are the key forms of activities they deploy these resources and capabilities towards?

3.3 Fair shake of the resource bottle

So, just what resources do these aerospace and defence firms have? This section proposes there are ten key classes.

3.3.1.1 Engineering and technical expertise

Distinct from an engineering and technical labor force, a contractor will have a network of highly qualified and very experienced specialists, covering a range of disciplines and skillsets. Even during times of cutbacks, firms will retain some minimum level of technical talent, often as a world-class subject matter expert. This core of engineering and technical competence is often recognised via a Technical Fellows program (or equivalent), and are often seen more as a centralised resource to be shared by various programs and projects the enterprise is engaged in.

3.3.1.2 Engineering and technical labor force

Whether in-house, contracted-in, or hired-in, the contractor has a strong pulling force for labor when required, aided particularly by the significant financial resources and brand reputation of the enterprise.

3.3.1.3 Financial capital

An often unseen, but very real resource contractors have at hand is large cash reserves – the leading firms holding the equivalent of anywhere between 5-20% of that firm's annual income[6]. This is not including the full accounting of assets held on the balance sheet, or monies owed. These cash reserves give contractors choices and options – such as to quickly hire in a larger workforce, acquire technologies or businesses, and/or resource the potentially expensive bidding processes to secure more work and revenue. A smaller provider simply does not have access to such cash reserves, and competitively positions these larger contractors in the market. A large cash reserve can also give customers a bit of breathing space, knowing that the enterprise isn't likely to go out of business and interfere with the delivery of projects and capability.

3.3.1.4 Technical data and information

Contractors, having worked on other projects or programs, will likely have large internal sources of data and information that will assist with the execution of the activity at hand. This information is not likely to be on the market and gives the contractor another advantage.

3.3.1.5 Intellectual Property

Apart from the technical data and information a contractor will likely possess as a consequence of involvement with past programs is the technologies, know-how, data, and legally-protected knowledge assets that the company either has invested its own resources in developing, the company has access to from funded research and development activities, or through partners via a program of monitoring and tracking technology development across the world. IP such as stealth technology was a clinching component of Lockheed Martin's successful bid to develop the F117 and U2 and came about due to efforts of understanding the state-of-the-art *outside* of the company.

3.3.1.6 Facilities

Production plants, maintenance facilities, and other facilities owned or under the control of the contractor means the customer does not need to pay for new facilities to be constructed and makes for a compelling reason to select that particular contractor.

3.3.1.7 Business development function

Having a well-staffed and resourced business development function allows the contractor to bid for more work, increasing the revenues of the business. One of the roles of the business development

[6] Observed from studying the annual reports of Boeing, Lockheed Martin & Northrop Grumman

function is to assess and plan how to reconfigure these resources owned, or made available to the enterprise.

3.3.1.8 Program management workforce

Such firms have a pool of appropriately skilled personnel who can plan and successfully execute projects and programs that the contractor has won. If additional skills are required, they're able to be sought out with superior wage offers.

3.3.1.9 Processes and governance

Contractors generally have a readily deployable set of processes and governance structures that can be rolled out in an efficient and timely manner to just about any activity. Rather than reinventing the wheel for each new activity, these robust processes and management techniques give great scalability to the various business activities of the company.

3.3.1.10 Political capability

Not a traditionally recognised resource, but for aerospace & defence firms, it's a necessary component of a successful company. Having the connections, influence, and reputation with key decision makers and authorities is the critical glue that helps secure future work, whilst ensuring existing work packages are performed to the benefit of the parties involved.

3.3.2 So where?

This inherent 'supermarket' of organisational resources and capabilities at the disposal of an aerospace & defence firm may be enlightening. However, if they sit dormant, the firm doesn't earn money. So, what are the various ways in which such firms configure themselves to execute contracts? This is the realm of business activity typologies.

3.4 Business activity typologies

As has been alluded to, aerospace & defence firms are difficult to explain as pure manufacturing enterprises, with a wealth of other programs and activities they're engaged in. This gives rise to putting some identity around each of these styles of activity, and 'noun-ifying'[7] them.

This is what is meant by 'business activity typology,' a term generated by this study to classify Complex Integrated Solutions as a different 'thing' compared to other activities such firms might be engaged in. In this study's view, a Business Activity Typology:

[7] This study apologies for butchering the English language

- Is an identifying feature to clearly delineate and categorise between different styles of business activity, even if they are similar in object (e.g., aircraft) or pursuit (maintenance versus sustainment-focused Solutions)
- Provides a boundary around an endeavour that has its own unique nature, nuances, and properties
- Helps managers and professionals realise that 'one-size-does-not-fit-all' by providing a class distinction by highlighting each typology needs its own management methodology.

It's also a useful concept to explain the myriad of contract and business activities a typical aerospace & defence firm will be engaging in on any one time:

- **Large-scale development, design and build programs:** Full-scale systems development, test, and production of a substantial number of new, complex systems (e.g., F35, tanks, some naval vessels).
- **Intensive, bespoke design-and-build programs:** An intensive development effort, but production is less mass-produced. Examples include submarines, several surface vessels, and some piloted and remotely piloted aircraft. For instance, specialist aircraft such as the SR71 and B2 bomber were costly to develop, but only a handful of aircraft were produced – the latter involving only 21 copies at more than $1billion a plane.
- **Bespoke platform repurposing programs:** A subset of the intensive, bespoke approach is special derivative of existing platforms to suit a new purpose or situation. In an engineering sense, the E7 Wedgetail and P8 Poseidon, as re-purposed derivatives of the Boeing 737 airliner are clear examples. Another approach for more political/commercial reasons is taking an existing platform, adapting it, and having it constructed in a customer's home country (either in part or entirely) as a temporary, bespoke production line, and in some instances, rename the platform. The Short Tucano in the UK (adapted from the Embraer EMB-312), the Hawk Lead-In-Fighter in Australia (from the Hawk jet trainer), and the T45 Goshawk (also adapted from the Hawk jet trainer) are some examples of this approach.
- **Systems Integration & Upgrade Programs:** Some R&D effort is required, but is more a bringing together of already proven technologies and/or platforms. Production efforts are limited and are not as intensive as a large-scale production program (e.g., upgrade of F16s).
- **R&D Projects:** Prototype development or technology demonstrator-style programs. Some bespoke manufacturing maybe required but is not a full-scale production effort.
- **Production/Tier 1 Programs:** production effort only of an existing design. Some of these programs may involve original, sub-contracted design efforts or other forms of Tier 1 partnering. For example, F/A-18 fuselage sections by NGC for Boeing.
- **Equipment & major component/sub-system programs:** the development and production effort of equipment that can be integrated into various platforms. Examples include radars and sensors, propulsion systems, communication systems, displays, and weapons.
- **Trade studies, consulting and advisory:** Piecemeal projects of smaller dollar value that focus on delivering intellectual products and contributions, rather than the fielding of specific systems. This is a growing field, and although work packages are smaller in size, the volume of various projects makes it a very worthwhile line of business.
- **Contracting staff/skills agency:** Much like a job agency, placing defence contractor staff into a customer organisation to work as a specialist as part of that team. The paycheck to that staff member is from the firm, but the day-to-day tasking and work effort is controlled and directed directly by the customer. The defence contractor is a job placement agency.

- **Process-driven Service Lines:** Contained, fixed, systemic services, such as logistics and spare parts order fulfilment, repair lines (e.g., repair of equipment), or non-complex training programs.
- **Complex service lines:** Services delivered to a customer that is more outcome-driven or comprehensive in nature. Complex Integrated Solutions fits into this category. Complex service programs can include integrated training programs (eg, ab initio training for pilots, where the contractor ultimately delivers a cadre of trained pilots to an airforce customer), or fleet and mission-enabling services (such as the case study 1) where all the effort for delivering the important assets and tools for a customer to perform their mission is provided. The customer focuses on the mission; the contractor focuses on ensuring asset availability.

This is not to say that such firms are expert specialists at each of these forms. Some may have greater strengths than others. However, understanding that these typologies exist is important so to develop strengths, but also to recognise each typology has its own nuances that need mastering.

3.5 Move over traditional factory

3.5.1 A new type of enterprise

So, what's the point of this chapter?

Firstly, what this chapter covers should be the focus of more thorough research and rigorous analysis. However, as an exercise in understanding more of the complex nature of such firms, it this chapter does yield an interesting perspective.

When examining major defence firms through this capability and business activity typology lens, it quickly becomes apparent that these firms are no longer just executors of traditional engineering design-and-build projects. They're motivated, and increasingly positioned, to go after anything that lines up between their inherent capabilities, and what the market needs. It shows that such firms cannot be classified as been pure manufacturers, or even as engineering program management companies anymore. Ultimately, these firms are service providers, too.

3.5.2 Independent providers

But what about independent vendors? As this study is focused more on the traditional aerospace & defence firm, independent providers are not explicitly referred to much throughout this study. However, such independent providers are likely to have their own portfolio of business typologies, but likely to be highly skewed towards service ones, rather than product development ones.

3.5.3 So what?

The core point of this chapter is that Complex Integrated Solutions can be offered by both 'manufacturing' firms or independent service providers. However, it must be understood that Solutions represent one of several offerings to the market made by such eligible firms. In addition, each of these offerings correspond to a business activity typology. This means that such firms need to develop broad repertoires, ones that may be at conceptual and resource odds with others.

This presents challenges for the embodiment of a CIS business activity typology into the repertoire of these different firms. The ‘host’ organisation may also have differing starting conditions, and thus the implementation into an organisation’s corporate routine may be quite different for different firms. However, the actual management methodology for Complex Integrated Solutions is likely be similar, even if the host organisation type is different. Hence, the results of this study will likely be beneficial for both ‘manufactures’ (aerospace & defence firms), as well as independent service providers.

CHAPTER 4

Getting to Grips with the Aerospace Sustainment Context

4.0 Sustainment as a Complex Service Program

This study looks at Complex Integrated Solutions of a sustainment and support nature. Chapter 2 outlines the opportunities that exist for firms to engage in the complex systems sustainment marketplace, and Chapter 3 describes some of the inner workings of the firms that seek to be providers of sustainment-driven Solutions. However, while this makes for interesting market analysis, the notion of service programs needs further examination, and the movement towards sustainment-focused Solutions also needs further attention to position this study properly.

There are many forms of complex service programs or Solutions in the aviation and aerospace context; thus, this chapter seeks to work up a concept of the *service program*. It's perhaps a concept familiar to many contractor firms; however, in aid of further understanding the comprehensive sustainment and support Solutions that are of a highly integrated nature, this chapter seeks to further carve out this type of program category in its own right, rather than default to a 'mashup' of other concepts.

This Chapter also explains some of the terms that are ultimately chosen and used throughout the study (except for the description of original concepts and research outlaid in Part II). This study uses various terms deliberately. It also structures its assertions on various constructs. This Chapter is devoted to explaining the language used, and the constructs that form the basis of this piece.

4.1 Making sense of the problem space

Trying to narrow-in on the seemingly moving parts and factors of a service/support/solution-driven concept/offer is complicated. This then makes it more difficult to more accurately appreciate the nuances and nature of the business models that occupy this space. This chapter presents some frameworks and remarks and sets the language to be used throughout the rest of this study to help make sense of this in-service epoch.

To assist in breaking down the key areas and issues that arise in this in-service sustainment and support paradigm, this study presents a framework shown in Figure 6. It's made up of the following layers:

- **Technical activities & management:** Namely, the actual technical activities associated with sustainment, including in-service engineering, maintenance, logistics and data management. Much of this realm is underpinned by technical disciplines with an associated, growing body-of-knowledge, as well as technical standards, management frameworks, and regulatory requirements. The body-of-knowledge gives rise to techniques and approaches to properly conduct technical sustainment activities (and the detailed management of those defined activities).
- **Service program management & contract execution:** This is the realm of running and managing a sustainment operation, and delivering results against some contractual obligation. Whilst the techniques and processes used in the above realm are the ways of accomplishing contractual obligations, how a service program is organised and operated is a business management concern.
- **Through-life sustainment/fleet management marketplace:** The realm of strategic factors that shape the in-service environment and its industrial landscape. These include major trends and policy shifts, and other global factors that might affect customer demand for sustainment programs, and the supply of suitable capacity and capability by prospective suppliers. The term 'servitization' appears at this level of understanding the sustainment context (discussed in more detail in Chapter 8). Much of the previous chapter, too, deals with some of the dynamics and developments at this level.

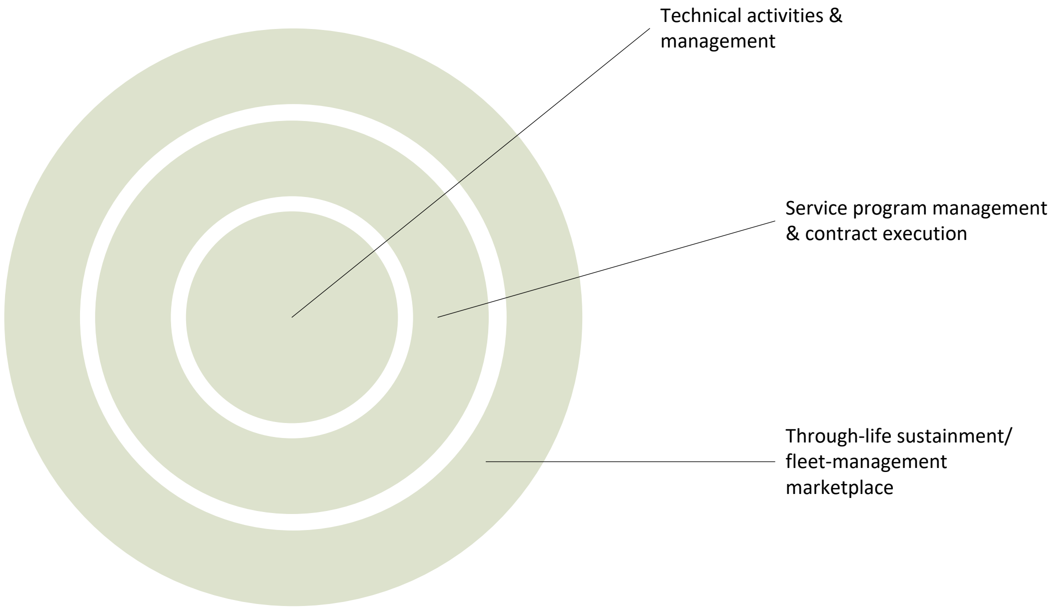

Figure 6: Analysis framework of published material in the sustainment context

It can be challenging to separate out the various commentary and concepts that play into this whole space; hence, separating this context out into various realms helps filter and better understand commentary and developments.

4.1.1 In-service environment

The 'aerospace sustainment context' is found in the construct this study will call the *In-Service Environment*. This is the operational environment where aircraft operators conduct their aviation affairs to further business interests (whether commercial interests for airlines, or force projection interests for military operators). Thus, it's the environment where an aircraft finds itself engaged for customer operations and use. The ISE term is a practical one, intended to capture the breadth and depth of activities that happen with an aircraft once it leaves the factory. It's a somewhat crude definition, as during the course of aircraft development, there are 'in-service' characteristics during flight testing, for example. However, the ISE term helps explain the context this study points towards.

It's in this ISE context that the realm of sustainment finds much of its expression.

4.2 What's driving the aerospace sustainment context?

The aerospace sustainment context is a space that is composed, and is being advanced by several factors. It's easy to be confused by the term *sustainment* given the multifaceted nature of its use. So, what is driving the aerospace sustainment context and the increased attention it has received in recent years?

The question is not just asked from a marketing perspective – that is the increasing need for aircraft maintenance, or increased customer acceptance of outsourced sustainment efforts. Rather, it reflects the nuanced and conceptual factors that are paving the way for a movement towards obtaining sustainment services by a Complex Integrated Solutions approach. This study asserts there are three key developments that are driving a clearer recognition of a Solutions approach to sustainment:

- Use of different business models – a new what
- A strategic opportunity/imperative – why
- An emerging discipline of sustainment – the how.

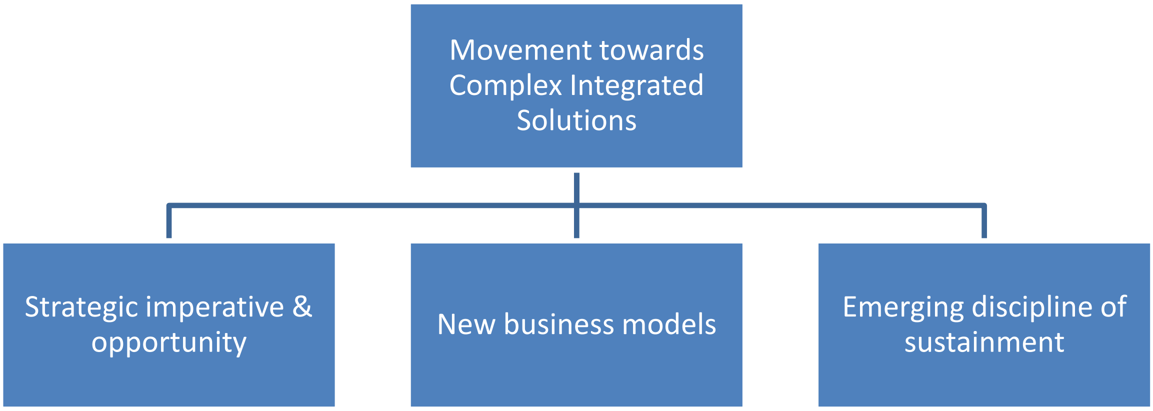

Figure 7: Key drivers of Complex Integrated Solutions

4.2.1 A strategic opportunity/imperative

As described in Chapter 2, manufactures are keen to embrace the sustainment and services world as a way of offsetting unstable sales cycles of new aircraft and systems, and sometimes, an overall decline in sales. In addition, entering the maintenance, support, and flying-as-a-service domain presents an opportunity for manufacturers to deploy what they determine as existing capabilities that can be exploited in other ways. This is the “servitization” strategy.

4.2.2 New business model

Manufacturers could (and in some instances, have actually) deploy these capabilities with little change. Entering into more activities using traditional business models, such as time-and-materials maintenance services, or fixed-rate contracts for upgrade and in-service engineering services are some examples.

Where this new paradigm opens up is in taking these existing capabilities, as well as developing new capabilities, and exploiting them in new and innovative ways. The Integrated Solutions approach is one such approach.

Customers are also being open to different and new contracting schemes that were normally performed substantially or totally in-house.

4.2.3 Emerging discipline of sustainment

Whilst less of a commercial source, the concept of *sustainment* has been making quite a profound appearance in the professional discourse of manufacturers, operators, customer contract managers, and third-party providers. It's a term that has come to mean several things to many people; however, given its increased prevalence, it is highly worthwhile exploring this field as it grows in its prominence.

Perhaps most notably, this study asserts that sustainment is emerging as a *discipline*, and not just as a *phase* or as a category of contracted activity. Where previously there were many disparate engineering and technical activities that affected the in-service operation of an aircraft, such as maintenance, logistics, and obsolescence management, this emerging field of sustainment brings these elements together under a more comprehensive banner of related knowledge and tradecraft.

4.2.3.1 From a phase to a field

As highlighted in Chapter 10, the story of systems engineering is echoed with the way in which certain localised specialisations came into being, such as logistics and reliability engineering. Jones describes how these various elements have gradually assembled into an engineering discipline (which he calls *supportability engineering*) focused on the support of systems that have "significant support challenges [53]".

Where systems engineering logic tends to pigeon-hole such efforts as a post-production activity, supportability/sustainment engineering addresses these challenges both in the design, as well as in-service contexts.

There are some additional observations worth noting that impact on the broader question about engineering in the CIS context. (This study would assert a few extra points about the emerging sustainment discipline.)

This study would assert that this emerging *sustainment* field is the grouping of similar specialisations into a more comprehensive discipline that deals with ensuring the upkeep, longevity and cost effectiveness of a system. It is expressed through various organisational functions/structures throughout an aircraft's lifecycle.

Whereas traditional approaches tended to focus on devising the maintenance program in-between the completed design, and the entry-into-service of a type, the sustainment discipline is found at every phase of the system's lifecycle, and is focused not just on the operational planning and execution of predefined maintenance actions, but on the longer-term management of a platform or system.

For this reason, activities such as ageing aircraft management, upgrade planning, obsolescence management, and life-extension programs come under this sustainment banner.

It is *product-focused* discipline. It's notionally an extension of systems logic – ensuring delivery of functionality – however, it is tempered with a stronger focus on operational outcomes, rather than product delivery ones. As such, it is a critical discipline that powers much of the technical efforts of various through-life programs and contracts, including the Complex Integrated Solution described in case study 1.

Sustainment, in this sense, is not a business model, but rather the set of activities for which there is a scientific basis, an active research and development element, emerging and clear professional standards, and training and education programs directed at raising professionals and practitioners steeped in this specialised knowledge.

There is a strong parallel with the transformation that Asset Management communities-of-practise have made, coming out of a "maintenance engineering" activity, to a more comprehensive discipline focused on assets/systems in-service effectiveness.

4.3 What are Complex Integrated Solutions?

There are many forms and styles of service programs. So, where do Solutions fit into the bigger context, what distinguishes a Solution from other service programs, and just what is a 'Complex Integrated Solution' that this study has referred to?

4.3.1 A wide variety

Something to add to the complexity of this discussion is that the term "Integrated Solutions" can cover a lot of ground, far beyond aerospace and aviation. This includes:

- Turnkey projects, such as establishing new monorail system and its operation
- The comprehensive rollout of a software system or tool across an organisation, such as Oracle or SAP
- Installation and support of office equipment (e.g., photocopiers) at a fixed fee.
- Citywide services such as town-centre upkeep (rubbish disposal, gardening, concrete repairs, etc.) or facility/office equivalent
- Bundled telecommunications services (fixed, mobile, internet, etc.) with an account manager and support structure.

Even within the aviation context, there are many instances where Solutions can be found. These include:

- Pilot training school – output of qualified pilots at a fixed price
- Running the check-in and ground operations for an airline
- Imagery and intelligence analysis for a national security customer
- UAS deployment to capture 'video hours', rather than merely support an in-field aircraft
- Airborne fire-tanker operations to support civic emergency service agencies.

This variety is very simplistically expressed in Figure 8, showing that in the in-service environment, Solutions can be sustainment-focused, or focused on other facets. However, as already indicated, this study confines itself to understanding comprehensive, sustainment-focused service programs.

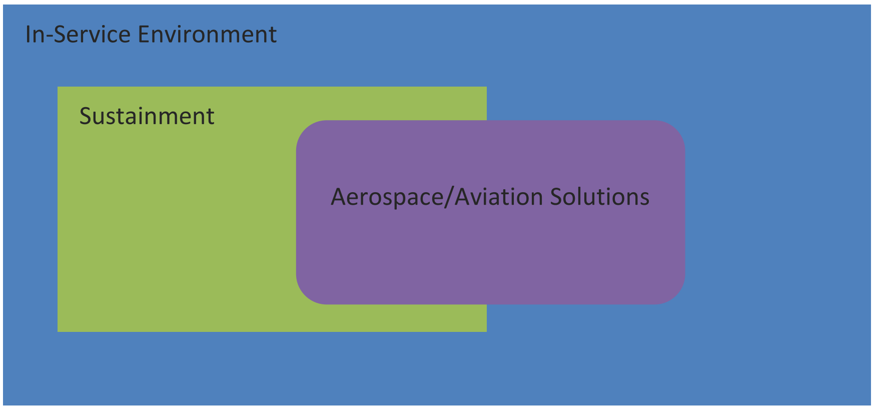

Figure 8: The in-service environment

4.3.2 Characterising service program spectrums

So far, this study has referred to Complex Integrated Solutions without properly expressing what this means. To better define and characterise CIS's, this study poses the *Service Program Spectrums* framework, a simple set of dimensions on which to plot and contrast service programs.

Service programs can vary in depth and complexity – from delivering just one item of a lower degree of sophistication (simple piece of software), through to high-repetition processing (e.g., component maintenance), through to assuming core customer activities (undertaking customer missions such as airborne surveillance missions).

Figure 9 presents three dimensions or spectrums along which many service programs could be plotted. There are three axes:

- Nature of Service Tasking
- Level of service element functionality
- Degree of customer or product centrality.

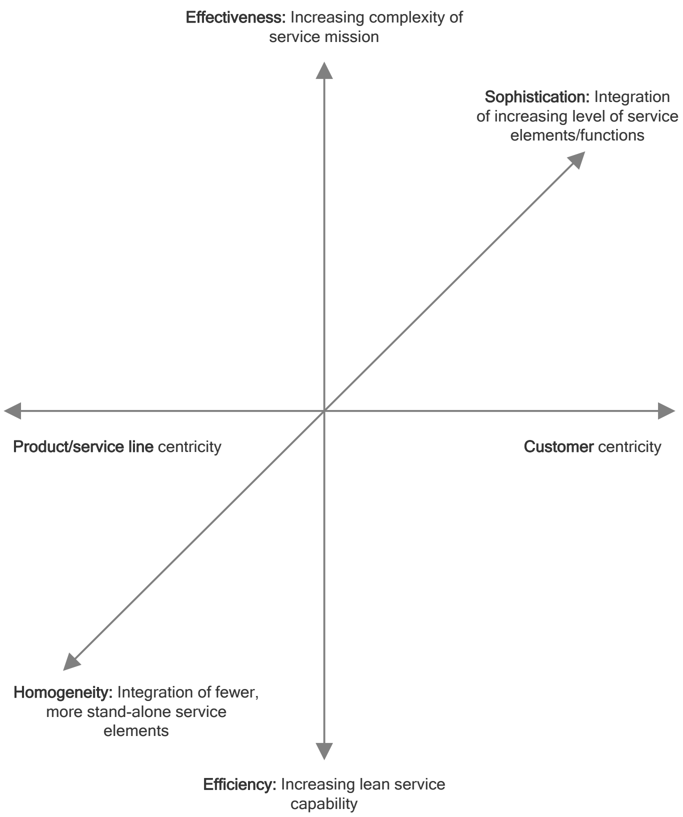

Figure 9: Service program spectrums

4.3.2.1 Service tasking nature

This relates to the expectations of the customer and the nature of the contracted service. Does the customer have a greater expectation for service efficiency, or service effectiveness?

Service effectiveness means having the capacity and capability to achieve a range of effects, including the need for flexibility in what is delivered/enacted, or responding to an uncertain demand profile; efficiency is a secondary consideration. **Service efficiency**, on the other hand, relates to producing a limited number of outputs or actions at high efficiency due to high volumes and smoother demand – a service operation is optimised to a certain speed, thus delivering the necessary efficiency. However, it does not offer a wide range of actions that may be required by a customer. This might be best colloquially understood as contrasting 'superman-versus-a-sausage-machine'.

4.3.2.2 Level of service element functionality

This correlates to the sophistication of the service program itself to the meet the customer need.

It might be straight forward, only utilising a few more straight-forward capabilities. The office fitout of a network of photocopiers might only require a handful of skilful, factory-trained technicians to setup, repair and maintain. A more sophisticated arrangement, on the other hand, involves a higher number of more complex product and service elements to achieve the customer's expectations, quite likely via many more modes of delivery. The aircraft themselves, the training equipment, the maintenance facilities and equipment, procedures, data, training and licensing regime, quality management system, information management systems, management regime, communications forums with the customer, the sizeable organisational structure of the outfit tasked with delivering the required service – and so forth.

There may be more service modes of delivery in the one integrated service program (Solution). For instance, the first case study (in Part III) physically delivers aircraft, spares, training devices, information and advice, among other intangible benefits (i.e., value streams) – plus, provides the Solution over several customer venues.

4.3.2.3 Customer or product centrality

Is the service program built around a customer, or a product/service?

It's assumed that most service programs will be customer focused in some manner, responding to some sort of customer need. However, this dimension really pertains to the extent to which the service program or Solution is actually designed and organised around *one* customer, or around *one* product line or service line?

By 'designed and organised', to what extend has the service infrastructure, delivery organisation and operation been intentionally designed and built around the capability offered, or the customer?

For instance, aircraft manufacturers offer several service programs around their major platforms – eg, B737 technical product support. This would be an example of a service program particularly designed around a platform. A high-through-put repair line for various hydraulic pumps and equipment to which customers send their items requiring maintenance in exchange for a serviceable unit is another example of a service program that is designed around a particular service offering – however, it is one many customers will have access to on a commoditised basis.

The difference with a service program built around the customer is that it a specific team, set of infrastructure and entire value proposition is raised up and implemented around a core customer need, and can often be embedded (to some degree) with the customer themselves.

Some services offer a blend of this. Field Service Representatives are a good example – embedded with the operating customer and responding to their specific needs, whilst plugging into a larger service program that is designed more for volume than for customisation.

4.3.3 Where do Solutions fit?

This study contends that Integrated Solutions fit in the right-hand rear half – in the realm of where services are primarily build around a customer.

However, this study deals particularly with *Complex* Integrated Solutions – service programs that are focused on effectiveness, exhibit high levels of sophistication, and are organised around a customer operation. As such, CIS's exist in the top, right-hand rear segment of the service program spectrum model. However, why is there a need for a *Complex* Integrated Solutions concept?

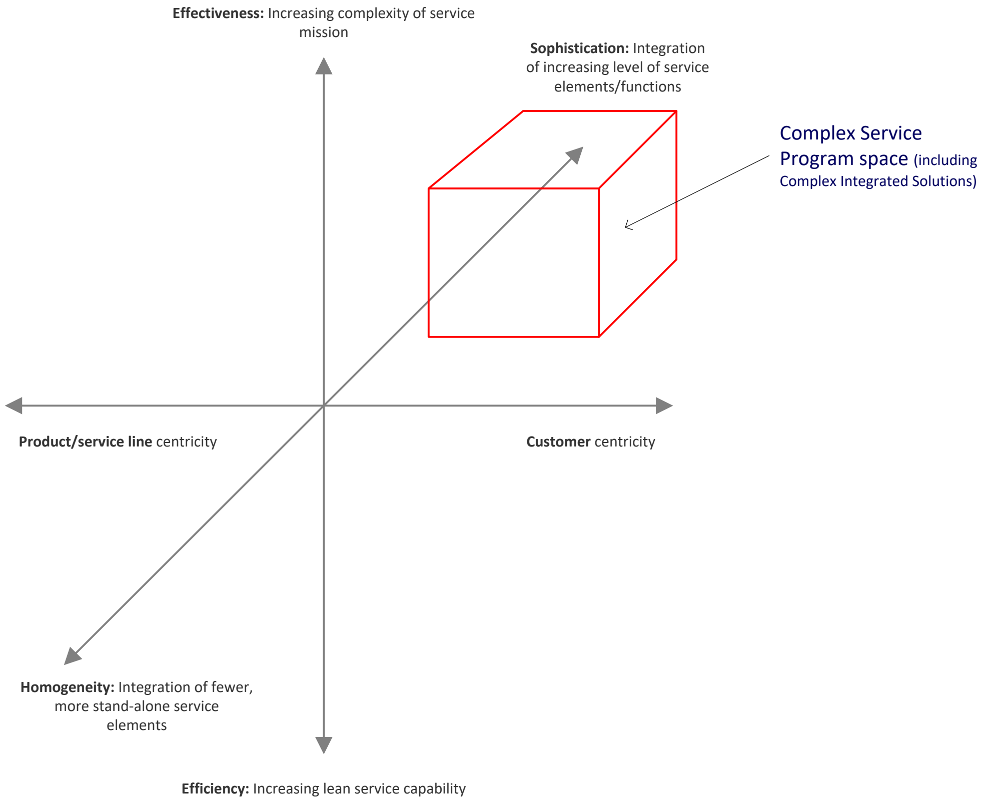

Figure 10: Complex service program dimensions

4.3.4 Why "Complex Integrated Solutions"?

The word *complex* is added to the presently renowned term *Integrated Solutions* due to the nature of the solutions this study is discussing. Not all 'integrated solutions' are created equal – lumping a 25-year availability contract of advanced jet-fighter trainers in the same conceptual bucket as office cleaning hardly seems helpful. Hence, this study refers to *Complex* Integrated Solutions.

This study lays down that a Complex Integrated Solution generally involves at least one of the following characteristics:

- Service provider is highly embedded in the customer's core business
- The service provider controls key/significant elements (such as assets, systems or infrastructure) vital to the customer's success
- Involves substantial design, research and development to pull the Solution together
- Involves some level of in-depth customisation, not just a rollout of existing systems with key features turned off or on
- Commitment and 'pre-work' to get to contract signature is an involved process, generally requiring more than presentations and proposals from marketing staff
- Outlays are at least in the millions of dollars per year, if not the tens-of-millions
- The Solution involves some sort of capital asset or advanced system.

It's a concept that's built on the following logic.

4.3.4.1 It's complex

Some "Integrated Solutions" are not all that complex – they combine elements together, but they are fairly straight forward elements. For example, Xerox offers an integrated solution in a seamless, printing Solution available to companies that are priced in per-sheet-price terms. It includes the physical photocopier/printer unit, onsite servicing, toner and fast-response service. Whilst it's *integrated*, it's not *complex* in that they are fairly well understood service/product elements.

The moment a fleet of modern aircraft are introduced into an Integrated Solution, it's hard to say the Solution is in the same league as a set of printers/photocopiers. Hence, the introduction of the "complex" suffix.

Complex is intended to represent and convey a number of facets:

- That it's an advanced Solution – there are many elements, whether product or service, that must be brought together in a conjoined fashion
- That it uses advanced/highly sophisticated product/service/system elements (often highly expensive, capital assets)
- It involves many critical components and elements (ie, high reliance on the reliability and performance of these elements)
- The customer's core business is complex and advanced. In other words, the Solution cannot merely provide simple, highly programmed input deliveries; rather, dynamic problem solving and collaboration are required to achieve what the customer needs.
- How 'success' and 'satisfaction' are measured is not straightforward – no one set of metrics can fully capture whether the Solution remains valuable for the customer.

4.3.4.2 It's integrated

To reiterate the point before, this class of service program/offering sees *integration* as the lynchpin in what distinguishes it from other service programs.

Further, it's not just one mode of integration, but several, including:

- Several elements brought together to address a particular customer imperative.
- The 'fix' to the imperative is not isolated from the customer, but deeply embedded and intertwined ('integrated) with the customer
- The 'fix' is not developed and delivered separate from the customer, but with the provider and customer working together (integration of efforts).

4.3.4.3 It's a Solution

The term *Solution* implies it is the answer or resolution to an issue. However, it's not merely solving a need in a particular point in time – rather, it addresses a pressing, ongoing need or challenge of some sort. It doesn't necessarily mean there is something broken – it may just be that a Solution helps improve a particular situation. In addition, Integrated Solutions, by definition, involve varying levels of customisation – to discover two exact programs would be remote, if not extremely rare. They are highly customised offerings, every single time. Thus, this study contends that a Solution is a well-crafted and enduring response to a pressing customer imperative.

4.3.5 A convention

Whilst this study is inclined towards describing this type of service program as *Integrated Solutions*, in itself it doesn't fully convey the comprehensive nature of what is been discussed. Thus, this study refers to *Complex Integrated Solutions*.

4.4 Choosing accurate language

To extend this approach of carefully selecting terminology to describe the Complex Integrated Solutions concept, it's important to consider some other terms used in this context. Language has the power to shape, influence and reinforce mental models [54], and thus certain terms can either build understanding of complex concepts, or led people astray with incorrect mental pictures and simplifications.

There are several terms that this study very specifically uses, or actively seeks to avoid. Namely:

- Sustainment
- Support
- Complex Engineering Services Solution
- Support
- Supplier
- Provider.

The weight and precise meaning of words will tend to vary between individuals. Thus these terms are the preferences of the author, with an explanation as to why.

4.4.1 Support & sustainment

Much of the terminology used in this space uses the term 'support' – such as Through Life Support, Support Engineering, Product Support, Customer Support, and so forth. Whilst the term is prevalent, this study shies away from it to describe key, overarching concepts.

Support is a 'catch-all' word with many meanings. Consider:

- It can mean a verbal expression of closeness or loyalty ("thank you for your support in this difficult time") or a general sentiment of encouragement;
- It can mean substantial financial backing;
- Receiving "OEM support", meaning to receive attentive, focused and energetic cooperation to resolve something;
- It can mean weapons delivery ("close air support").

It's a useful, perhaps euphemistic term that can be deployed in many contexts, and has a very legitimate presence in the context of in-service support. However, it is imprecise without substantial and explicit qualification in its context.

In addition, support can sound passive. It has a 'stand-by' meaning to it – for example, an operator will only draw on 'customer support' when there is a problem, but when things are operating as required, does not require that support infrastructure. In the in-service context, it can also infer a 'crisis-response capability on standby for the very long time this product is going to be with us (the customer)'. It has the potential to limit the meaning of a 'through-life support provider' to an on-call problem solver, and does not immediately convey a sense to the customer – especially if it's not just a crisis-response service – that there is a lot more activity that the service provider is undertaking to ensure that for the majority of the time, things run smoothly.

Hence, this study prefers to use terms such as *sustainment*, or *solution* in instances where the customer and the provider need to share a common term (terms like *service program* are useful when referring to or describing the body of activity within the company). Such terms subtly acknowledge that there is underlying infrastructure and systems that a customer gains access to – a hidden formwork that is highly beneficial, like the plumbing in a building that provides water on demand.

S*ustainment* in particular is preferred when referring to the complex technical activities associated with long-term upkeep of a fleet. It subtly implies a broader ensemble of activities directed towards some enduring goal, and conveys this in a more active tone. However, it's important to note that the term *sustainment* alone is not sufficient to be the keystone term for the concepts to be explored in this study. Sustainment infers maintaining the status quo and ensuring it does not go backwards, yet the concept of Complex Integrated Solutions is more than this.

Perhaps a perfect word does not exist, but terms like *solution* perhaps are as close as one can get to articulate the experience of having a live and dynamic stream that delivers something valuable on a continuing basis, and not just the standby crisis shopfront. It encapsulates the ideas of having a formwork that is churning out something beneficial, but is sufficiently flexible to meet changing needs of customers, rather than be fixed around some immovable technology or operating concept.

4.4.2 Supplier, provider & partner

Aircraft manufacturers as well as service organisations are often classed by customer organisations as *suppliers*. This study asserts that the term *supplier* sets up wrong expectations about Integrated Solution programs, and should be avoided. It can readily insinuate:

- A service stream that can be turned on and off again
- That services 'are pre-produced, sit on shelves, waiting to be shipped'
- That the customer is the sole-source of wisdom and can issue service-taskings for inputs of their exclusive choosing, despite contracting the service provider because of the expertise and intelligence they bring
- A predominately one-way conversation, rather than a collaboration.

Given the nature of services, such as the formwork that's required to deliver them, and their co-production nature, this study asserts a customer should, at the very least, look to the 'supplier' of a CIS as a *provider*, and preferably a *partner*. *Provider* yields a similar sense to a supplier – an entity that gives. However, what this service provider is actually delivering is more 'captured' in the noetic domain (i.e., benefits), rather than in the physical domain ('things').

Preferably, customers would view CIS providers as *partners*. Apart from the obvious notion of collaboration, a *partnership* is a more accurate term that reflects the highly tethered nature of such Solutions – the CIS provider holding a key-piece of the customer's puzzle, and one where the provider has their customer's back (but also where if they stumble, could cause significant harm).

The customer ultimately is the key driver of the Solution. However the advantage a CIS approach provides is intertwined in what the provider and customer build *together*. To demand the 'Solution provider' to assume the role of a bespoke service supplier (an output business) would likely be a misuse of money and resources.

4.4.3 Complex Engineering Services Solution (CESS)

This study doesn't continue to use the term CESS (as described in Chapter 7) for two reasons.

One, it lacks the term "integrated". This study asserts that a key facet of this type of service program is that they are *integrated* in nature. There are many different types of activity that have to be brought together and delivered by the one service unit, and generally all that activity is paid on the one bill.

The second reason is because "engineering", whilst useful to explain the nature of the service operations to deliver the Solution, can be misleading. It *can* imply the only output and outcomes the Solution seeks to deliver are technical. In this context, this study seeks to convey that ultimately Solutions are a business transaction where business needs are satisfied (not just technical ones), and the phrase *Integrated Solution* tends to reflect this intention slightly better. Ideally, there would be a technical/engineering reference, but for sake of brevity, it's left out.

4.5 So what?

Is a chapter such as this one really necessary? Perhaps not entirely. However, it does present some 'digested' perspectives on the realm of aerospace solutions, and attempts to better frame the context to boost clarity of a space that can become dense quite quickly. It also lays down some of the logic to be carried through this study, and explains some of the thinking behind some of the potentially unorthodox conventions this study adopts. It also helps with framing what this study strives to uncover: insights to help inform and build a management methodology for sustainment-focused Complex Integrated Solutions.

CHAPTER 5

What is this Study Trying to Discover?

And What is a Management Methodology?

5.0 Mental maps & winning wars

By 1942, a rapacious Japanese army was poised to dominate Asia. The British had withdrawn from its colonial strongholds in the region, and with the powerful Japanese army now occupying Burma, it was seemingly poised to advance and eventually take India. However, the Japanese ceased making advancements on this front and never sought to overthrow the British Raj.

Why? In a fascinating piece of research by Dr David Brewster, he explains that the Japanese leaders simply “did not see the Bay of Bengal to be a single strategic entity – rather, there was a dividing line between their ‘mental map’ of what constituted Asia and the Indian subcontinent beyond [55].” Brewster continues by arguing that “our mental maps of the world, including our perceptions of where regions begin and end, can have profound consequences on strategic behaviour.”

5.0.1 It starts in the mind

But what has this got to do with sustainment-focused Complex Integrated Solutions?

In short, it’s another striking analogy of this study’s raison d'être. That one’s mental lens can form conceptualisations about the world – or about the sphere of business activity one is engaged in – and this affects the way that activity is interacted with and managed. Much like the opening anecdote of Microsoft’s disastrous investment in aQuantive, one’s idea of how ‘things are supposed to work’ may be at odds with the nuances and nature of that particular activity or context.

This chapter describes a concept that is the intended intellectual vessel into which the insights of this study are poured and the reasons why it’s pursued. This study refers to this concept as *management methodology*. It’s also a more ornate way of capturing the essence of terms such as “management logic”, “management approach”, or “management philosophy”. However, it’s a complex field that calls on psychology, economics and organisational design concepts; hence why the term “methodology” is used, to give the concept a sense of being rigorous with a strong sense of logic, but that also exudes tactics and action.

In short, it's a concept that refers to managing a business activity or endeavour according to its nature, but it also reflects the power a strong management methodology can yield: a clarity that inspires confidence and directed action and movement. It's a concept behind corporate cogency.

5.1 Thinking about thinking

Whilst *Management Methodology* is not a term used in literature, it's steeped in the works and ideas of four leading management thinkers:

- The notion of 'the organizing,' as opposed to 'the organisation' by Karl Weick
- Mental models with Peter Senge (although mental models are espoused by many (including Weick); Senge just amplified its use)
- 'Fast and slow thinking' (System 1 and System 2 thinking) by Daniel Kahneman
- The notion of default thinking and its crude cousin the 'curse of efficiency' by Dr Jason Fox.

5.1.1 Mental models

The first use of the term "mental models" dates back to 1943 where Scottish psychologist Kenneth Craik [56] discussed "small scale models of external reality and of [an individual's] possible actions in [their mind]". However, the concept particularly hit the forefront of management thought (so to speak) in Peter Senge's seminal work *The Fifth Discipline* on learning organisations [57]. In it, he unpacks the notion of mental modes this way:

> "Mental models are deeply ingrained assumptions, generalizations, or even pictures of images that influence how we understand the world and how we take action."

It's a concept Karl Weick [54] picks up on and puts into the safety context, suggesting safety-sensitive professionals accumulate unnoticed events that are at odds with accepted beliefs, and instead of deferring to static conceptualisations or interpretations of past experience, they constantly challenge the status quo of what they understand (i.e., their mental model). In doing so, they generate a much richer view of the safety-critical context they operate in, helping to identify and prevent a disaster.

5.1.2 Fast & slow thinking

Nobel prize holder, Daniel Kahneman, combines psychology and economics in his fascinating book from 2011, *Thinking, Fast and Slow* [58]. In it, he espouses that there are two key modes of thinking that he describes as two systems of thought – one 'fast', the other 'slow'. 'Fast thinking' is a style that is instinctive, 'emotional', automatic, on-impulse, stereotypical and subconscious; 'Slow thinking', on the other hand, is more considered, measured, deliberate, calculating, and reflective.

5.1.3 Default thinking

Fox extends Khaneman's ideas about systems of thinking to another level, articulating that 'fast thinking' represents a default style of thinking – an automatic response ideal for efficiently tackling routine problems and executing formulaic work [59]. However, Fox also explains that it suffers from a fatal flaw – it's not good at more strategic, nuanced and complex or equivocal problems or situations, such as mapping out possible futures for an industry or company. Non-routine and comprehensive problems deserve a deeper, calmer, more considered thought process that doesn't really have a 'right answer' (but whose 'wrong answer' can be costly).

5.1.4 Organisations-versus-organisings

In a separate stream of logic, yet relevant to this discussion on management logic, is an unorthodox view of how 'organisations' work. Weick [60] views it like this:

> "The word, organization, is a noun and it is also a myth. If one looks for an organization one will not find it. What will be found is that there are events, linked together, that transpire within concrete walls and these sequences, their pathways, their timing, are the forms we erroneously make into substances when we talk about an organization."

By using an active term to describe the process of organisation 'being', he expounds a concept where an organisation is far more than its structure or reporting lines. This point is brought to light in an earlier work [61] where he explores how organisations are "enacted". He argues that "organising" is in fact about reducing equivocality (uncertainty) through information processing, and is a pursuit by individuals to find ways of coping with their often-uncertain environments.

5.1.5 So what?

It's this logic that underpins this study's concept of a management methodology – primarily an organising concept that seeks to reduce ambiguity and increase confidence to act in a cleverer fashion.

5.2 So what is a management methodology?

Based on these four ideas, this study puts forward a mental formwork to help better contextualise the contributions made later in this report. Rather than a series of ideas 'swinging in the wind', they help form a sphere of knowledge that has a practical end, even if it sounds academic, theoretical, or 'management speak'.

So just what does this study assert is a management methodology? As it forms a powerful technique to understand a concept, what *isn't* a management methodology?

5.2.1 What it isn't

There are probably more points that could be added to this list, but the following three points are still highly instructive:

- **It is not the same as management style:** Where 'management' style is meant as an alternate to 'leadership style', it reflects a personal and individual approach to how a group of people are led/managed due to individual's character/personality traits. Instead, management methodology refers to a logic for managing a style of business activity.

- **Activity, not people:** In a similar vein, management methodology focuses on the style and nature of the activity or task, rather than how to manage the people element (noting there is significant overlap, and such a methodology will inform how to manage people in such a context best)
- **It's not strictly the same as a mental model:** A mental model is something that is formed by an individual's thinking and sense-making practise, and is thus unique and specific to that individual. Mental models are dynamic (some more than others) and change as an individual processes more information and experiences. However, a management methodology will certainly help guide and fashion an individual's set of mental models.

5.2.2 What it's intended to refer to

Returning to what *is* a management methodology, it's important to start with an appreciation that this concept is but an invention of this study to help explain in a practical context the research and ideas found in this study, and to provide a pathway for its application. It's not a term found in existing published management thought or research. It could also be considered the 'mental shelf' on which to place the insights and ideas generated throughout this study.

In short, this study asserts that a management methodology is simply a management logic that helps guide leaders, managers and other professionals through the complexity of their respective activities and help secure success.

On a practical level, the level of sophistication to operate and ensure the ongoing effectiveness of a sandwich shop is clearly very different to that of a global bank; operating a small accounting firm is very different to that of a supermarket chain; a small garage mechanic's business is very different to that of an airline. The concept of management methodology is to build an explicit/clearer archetype around a business activity typology that helps grow understanding of the unique nuances of that activity to aid running that business in-accordance-with that activity's nature. It harks back to the introductory anecdote of Microsoft running another firm in a way not suited to its unique aspects and market nuances.

To unpack this a little bit more, this study also suggests that a management methodology also reflects the following properties:

- Exhibits a management philosophy & approach of how the style of an activity/task/responsibility set is normatively approached (the ideal standard or 'normal/correct' way of doing something; in other words, the concept that tells one if a grouped business activity is being done 'properly').
- Lays down organising concepts for a style of activity or grouped-tasks – principles, 'unwritten rules', imperatives (whether obvious or subtle), and frameworks that help leaders and professionals to understand their collective activity and responsibility, and to be 'organizing' effectively for it. This logic then translates into organisational structures, key routines, key infrastructure, policies, processes and procedures, and other organisational formworks.
- Presents a mental formwork on which to build mental models to understand, make sense and effectively prepare and manoeuvre through the unique challenges faced by that line of business or activity.
- Helps illuminate the sphere of awareness a manager or professional should seek to cultivate to properly manage that realm of activity (and beyond); expressed another way, it is the logic used to assert whether something is (or is not) the problem of that activity-based group.

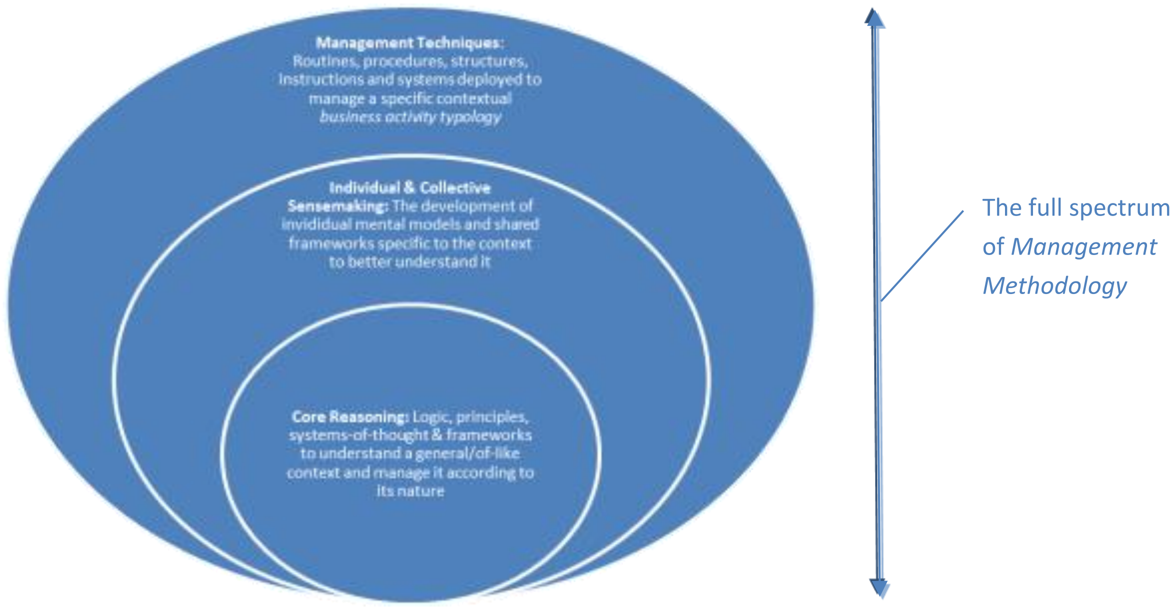

Figure 11: The management methodology 'onion'

Understanding the management methodology concept can also be understood from the effects that it can generate within leaders, managers and professionals:

- **It gives people a mental head-start:** It can present managers and staff with a sense of a preloaded deja vu – a situation where an individual can recognise obscure situations, and be able to understand (and then respond) quicker.
- **It frees up mental capacity:** and divert that capacity to solving problems, or at least understanding them quicker, rather than spend valuable time trying to build a mental model of a situation from scratch.
- **Higher cogency:** It can enable individuals to act with greater cogency, familiarity, with less stress and less ambiguity.

5.3 What this study seeks to uncover/reimagine

5.3.1 Finding a management methodology for Solutions

Moving on from this exposition of a management methodology, it's important to now focus on a critical question: just what is this study trying to discover (or as the case might be, try to reframe and reimagine)? Deeper still, *why* does it need to do this?

In short, this study is about contributing original insights and ideas to a colloquy (albeit an indirect one) on how to operationalise, run and manage Complex Integrated Solutions – to use the language of this study, a *management methodology*.

It doesn't provide the full answer by any means. In fact, much of this study won't feel like it's connected in much meaningful way to the pursuit of a more refined management methodology. Its approach is to understand the concept, rather than provide an immediately implementable management system of frameworks, processes and routines (although certainly some of the concepts posed could easily be converted into such). It helps to do this by further carving out – or, colloquially speaking, 'thingifying' – the Complex Integrated Solutions concept and distinguish it as a legitimate and established way of doing business, thus making it a more visible business concept for which to build a management methodology around.

This study's approach is also to think deeply about concepts that are perhaps taken for granted. Readers will notice a subtle switch from seeing concepts such as sustainment, maintenance and engineering from a 'fast-thinking' System 1 perspective, and instead from a 'slow-cooked' System 2 exploration, with the aim of helping to build a new System 1 thought process. In other words, the intent of this study is to help construct a new instinct.

5.3.2 But not finding a way of transforming

It's important to note, however, that this study doesn't offer a great deal of commentary or insight into how manufacturers might seek to servitize and transform themselves into highly proficient Solution providers. It's certainly a fascinating topic, one examined by several researchers (found in Chapters 8 & 9). However, that's not to say there are not things that cannot be learnt from this study for that purpose.

5.3.3 Key questions

Sustainment-focused Solutions can easily open to a very wide berth, so what exactly will this study examine?

In the colloquy context of seeking a more refined and nuanced management methodology, this study seeks to address two key questions:

- What are some fundamental properties of Complex Integrated Solutions that would help fashion a more precise management methodology for it?
- What is a new archetype for the Embedded Engineering Function for aerospace Complex Integrated Solutions (particularly those involving managing and sustaining a fleet)?

The first question may appear fairly clear, but why an emphasis on the 'Embedded Engineering Function'? And for that matter, what is meant by the EEF in the first place?

5.4 Why explore the essence of engineering in the in-service environment?

5.4.1 Narrowing in on the key engineering players

To understand the 'Embedded Engineering Function', and why this study seeks to look at it along with Complex Integrated Solutions, it's important to first consider the various groups, roles or styles of engineering in the in-service environment.

In short, there are three key types of professional engineering units that one may encounter in the in-service environment:

- **Operator embedded:** The engineering unit attached or embedded with the operating customer of an aircraft fleet to ensure the continued airworthiness of that aircraft, and is generally a part of the organisational unit that performs maintenance and aircraft support supply chain management.
- **OEM/Design Approval Holders:** Airframe, engine and major systems engineering organisations that have developed the system that is in use. It provides a deep product support backing to operators to ensure the continued safety and effectiveness of the products and systems the operator has in their fleet. Such organisations are generally recognised by airworthiness authorities as 'design approval holders'. This also can extend to bespoke upgrade/modification approval holders for major changes to a localised fleet.
- **Specialist engineering support:** Specialised engineering consultancy firms that provide independent specialist or non-routine support to an operator. These range from providing repair, modification and upgrade design services, forensic engineering support for technical investigations, and specialist performance and operations engineering support. In the Defence context, science and technology support organisations may provide this capability.

It's this 'operator embedded' form that is of particular interest to this study.

5.4.2 The Embedded Engineering Function

This study seeks to look in closer detail at what this study will term the *Embedded Engineering Function*. It's the 'engineering' unit imbued in the operator's business (whether as a part of the customer's organisation, or as part of a Complex Integrated Solution) that is charged with the sustainment of the fleet and the technical support of the flying operations group.

However, drawing a box around just what is the EEF is not as straight forward as locating "Engineering" on an organisational chart. It can be known by a number of terms, such as the Continuing Airworthiness Management Organisation (CAMO), Technical Services, or the Engineering Authority (to name three possibilities). It can also be easily overlooked or mistaken for units that sound like they're engineering, but are actually implementation or coordination focused, such as maintenance planning or a technical helpdesk that is capable of responding only to routine issues with pre-prepared answers. It can even be a function that is divided over several units across an operator's organisation.

As such, there are some key qualifiers to identify what exactly is meant by the Embedded Engineering Function within an operator or Integrated Solution community:

- The unit, or network of units, that require professional engineering oversight, control, direction, attention or effort and where the majority of the staff are professional engineers, or whose decision-making posts are held by professional engineers;
- The unit charged with the responsibility for continuing airworthiness for a given fleet (a concept expanded upon in Chapter 11);
- A unit where significant levels of professional judgement and formal technical knowledge must be applied to solve both routine and non-routine technical matters (That is, the noetic technical analysers and problem solvers);
- A unit whose decisions (rather than actions) directly affect safety and the technical integrity of an aircraft;
- A unit that has some form of technical policy setting, control, and recognised capacity to issue authoritative instructions for other units to physically carry out on an aircraft fleet.

5.4.3 Why focus on the EEF?

So, why focus on the Embedded Engineering Function as part of a quest for a management methodology for sustainment-focused Solutions?

Firstly, because building a clearer logic around engineering outside of the product-development world is one still ripe for development and exploration. Getting to the core of what engineering truly is about can be an enlightening ontological journey that shines greater light on the whole profession that is *Engineering*.

Second, because the professional Embedded Engineering Unit is an essential organ of any sustainment and support-driven Solution, even if pinning down the exact logic of its essence is not always straightforward. Engineering is the 'secret sauce' that gives an operator/Solution provider greater control over producing desired business effects with technological complexes, such as aircraft systems. Of course, not every sustainment-focused service program may have such an EEF; maintenance contracts that are highly formulaic in nature that is focused purely on implementation of other units' instructions, is a prime example. However, for a truly Integrated Solution that seeks to offer its customer greater flexibility needs to have control over far wider aspects of its affairs. This is institutionalised with an EEF.

Third, 'Engineering' units are often formed as the housing or basing of technical experts and 'cleverness'; however, understanding engineering as a corporate or business function, especially in a sustainment and support context, must surely be a little more nuanced than simply a condensed 'brains trust'. This study would assert that it's an organisational function in need of a clearer conceptualisation of what effect it can produce, and thus in need of some clearer organising principles to achieve that end. In other words, a Solutions management methodology and logic that extends to one of its critical enabling functions.

5.5 Why is there a need for a management methodology for Solutions?

It's important to return to a question asked two sections back: why does this pursuit for a more nuanced management methodology matter?

This study identifies three key signals that there is a need for a contribution to a management methodology for Solutions:

- Literature review on Solutions
- Concepts for sustainment management
- Observations from the case studies.

5.5.1 Solutions research

A literature review suggests that there is a dearth of researched understanding and ideas of how Integrated Solutions are designed, built, delivered and managed, especially if implemented by a traditional manufacturing firm that is seeking to 'servitize'. While there exist several pieces of research on Integrated Solutions, whether exploring generic challenges facing the concept, putting a generic theory around the concept, or providing commentary on corporate service strategy or Solution implementation, there's little research on the actual means of managing Solutions that yields actionable insights. Some of the research points to the complexity of Solutions leading to circumstances where designed processes are by-passed, and that there is a real research challenge for finding ways of "contracting, designing, engineering, and delivering end-states that include both deterministic outputs and emergent outcomes [62]." In short, there's a shortage of needed ideas and insights for how to manage Solutions on an ongoing basis, and not just implementing a change in corporate strategy.

5.5.2 Sustainment management material

Whilst there is an increasing level of material covering techniques for sustaining aircraft for efficiently and effectively, there does seem to be a dearth of organisational theories, concepts and frameworks even for conventional aircraft maintenance operations (at least a well-explained logic that goes beyond regulatory requirements), let alone sustainment management. For example, there is only really one seminal text on aircraft maintenance management [63]. Thus, finding implementable concepts and frameworks that form the basis of good organising principles for a sustainment operation are not in abundance (see Chapter 10 for further discussion).

5.5.3 Case study observations

When reflecting on observations from both case studies, there appeared to be an unsettled approach to managing a Solution operation. In addition, organising and management concepts that were implemented seemed to be adopted from other means of organising for technical programs, such as development projects or conventional maintenance organisation concepts. The effects of these non-optimal approaches, as revealed, did not cause safety issues. However, they were still not completely effective archetypes, leading to delays, misalignment of goals, and causing other friction points in the smooth delivery of the Solution.

5.6 Systems Engineering: A default management methodology?

One more reason for pursuing a management methodology for Solutions is so to circumvent the temptation to adopt another management methodology by default (something alluring in a drought of acuity). Perhaps one of the most prevalent systems of thought that dominate the aerospace context is that of *systems engineering*.

It's a powerful and alluring methodology for 'transforming customer needs, requirements and constraints into a system solution' [64], and presents many cogent ideas and frameworks. Many practitioners in this field will be highly familiar with its key tenets and epithets, such as:

- The concept of function, not merely physical form, as the goal of system design (including specifying and pursuing system behaviours, synthesised by a functional breakdown structure, and not merely a component structure)
- The lifecycle approach for planning, management & control (and which feeds into key concepts for project/program management)
- The 'V' process – the actual means of accomplishing system engineering. This includes analysis, architecting and development steps to ensure a consistent approach to an identified need at a point in time.

This study asserts that systems engineering is the major and engrained management methodology found particularly in major system manufacturers (such as aircraft manufacturers). It's by no means the only major system-of-thought in play, but System Engineering's frameworks and thorough conceptualisations make it a very powerful body-of-understanding (as well as body-of-knowledge). With product development being the dominate mode of engineering in the aerospace context, it then follows that it's tempting to be brought across to other aerospace pursuits, such as sustainment.

It does raise an important question: as the very basis and fabric of the systems engineering approach is rooted in new product development, is it a suitable system-of-thought to carry across to the sustainment context?

5.6.1 The weakness of the Systems Engineering approach in sustainment

In short, not really. Much of the systems engineering thinking and models that are traditionally used when solving customer problems, especially in the engineering space, are driven by linear thinking [65], and whilst a useful approach for developing advanced and complex systems, are only capable of handling predictable properties and requirements. It's an approach not suited to the emergent and dynamic environment that is the sustainment context.

Wood & Tasker put it this way:

> "The system engineering thinking style is deeply embedded in the development of complex systems [and]… is perceived to be inextricably rooted in the product paradigm ensuring a cultural rigidity inhibiting development of the method to accommodate design in the social space necessary for the attainment of service excellence. It is therefore important to develop complementary techniques for service design in the social space based on ''service thinking'' and the theory of mind…[65]"

It's the fundamental assertion of this study that a new system-of-thought for sustainment, and in particular, for complex service programs (including Complex Integrated Solutions) needs to be fashioned and clearly articulated. Further, it makes the verified assumption (based on authors such as Wood & Tasker) that it is not a sufficient or suitable into a sustainment sphere in an unreformed manner.

There are some practical reasons for this, too, beyond consistency of logic. In particular, even though Systems Engineering standards and textbooks might incorporate operations or support in its frameworks, simply reviewing the level of content such frameworks (such as the IEEE [64] or INCOSE SE Handbook [66]) devotes to this space is revealing. One leading textbook [67] devoted six pages to in-service support, with the majority of the book devoted to product development. Even references devoted to logistics and supportability engineering are steeped in Acquisition Logistics (support engineering performed during system acquisition), rather than as an in-service operation. It's a dearth of knowledge that is expanded upon in Chapter 10.

5.7 Research methodology overview

Rather than dropping systems engineering altogether, evaluating the merits of systems engineering logic applied into the sustainment context is a potentially feasible approach, one performed in part by Wood & Tasker. However, this study has chosen to take another approach.

Instead, it takes a 'first-and-a-half'-principles approach by learning from two real-life case studies, expressed from a Solutions standpoint, including been viewed through a service 'dominant logic' (explained in Chapter 7). Case studies provide powerful, rich learning opportunities that can capture nuances and phenomena not always recorded by more rigid techniques (further expanded upon in Chapter 12). Letting the case's narrative speak for itself can highlight factors previously undetected and can help generate insights that are founded on these first-principle observations. This is, in contrast, to merely presenting a recycled concept, such as a systems engineering worldview that is only tempered slightly by case-study insights, yet posits only a potentially watered-down and unreformed concept.

It's not to discount this 'reformed' systems engineering evaluation approach; it likely has merit. However, this study goes beyond managing the technical or subject matter aspects of sustainment operations (i.e., the detailed processes and techniques, often prescribed by technical standards or by regulation, to manage a complex system). Instead, it extends further back into the corporate aspects of the Solution delivery provider, and instead becomes an approach about how the Solution delivery business is managed (e.g., how it organises itself to collaborate with a customer), not just its engineering activity (e.g., how to track and control a fleet's technical configuration). Hence, it adopts this fresh approach.

5.8 Rewriting the playbook

So, it this investigation and effort really all that important? And why does this study offer such a spirited defence of the concept of a “management methodology”?

In short, it’s easy to dismiss the insights generated in a study such as this. The publishing of management frameworks can easily come across as ‘consultant speak’; designed to woo clients, but be short on substance, and thus open to being dismissed as ‘a passing management fad’. However, this study contends that there is something deeper going on when new frameworks or ideas are presented. Instead of corporate speak, they instead offer insights, clarifications, but more importantly, opportunities – opportunities for professionals to build their own mental models in ways and levels they’ve not been able to before.

This can lead to greater clarifications with greater and greater precision, granularity and nuance. In turn, this can help managers, leaders and professionals to understand their domains better, so they can respond with greater decisiveness and incisiveness.

This study doesn’t at all purport to be a full, encompassing and complete management methodology for sustainment-focused Complex Integrated Solutions; it’s merely a contributor to it. However, it does offer insights and ideas that help increase the stocks of an important management currency: Cogency.

CHAPTER 6

Engineers Don’t Just Build Bridges

6.0 What is engineering, anyway?

In 2009, Engineers Australia pioneered a new marketing campaign [68] to adjust public perceptions about engineering. Their research concluded that the ordinary person on the (Australian) street thought that engineering was little more than a profession that "built bridges." To counter this narrow view, EA launched a campaign called "Make it So," asserting that engineers were the people society could count on to 'make things so.'

As part of the campaign process, Engineers Australia initiated a 'BBQ competition' whereby their members provided 'BBQ descriptions' of how they'd describe engineering to their friends around the BBQ (naturally, the competition winner won a BBQ). What resulted was the simple, profound expression to make engineering clearer to the broader public: *Engineers Make It So*.

Slogans aside, such an exercise raises some profound questions – what exactly is this pursuit called *engineering*? What does an engineer actually *do*? What actually *is* an engineer?

By their nature, they are questions steeped in a realm of philosophy that few engineers seldom embrace, and whose answers are not always clear-cut, despite no shortage of academic definitions.

6.0.1 Why bother?

The field of engineering philosophy is not the scholarly field this study seeks to place as its central line of inquiry. However, it is a fundamental matter that underlines much of what is discussed in later sections, and thus requires an informed, working concept of what engineering is really about. And like any 'big-picture' question of a philosophical nature, much understanding of the engineering profession is found back where it all began.

6.1 Of philosophers and engineers

The realm of asking 'big picture' questions about the engineering profession is something that is expounded in the scholarly pursuit of *engineering philosophy*.

Science has a strong tradition of philosophical introspection. Authors such as Popper [69], Khun [70], and Polanyi [71] have each contributed significant arguments and understanding concerning the role of science, the method of scientific discovery, and the characteristics of scientific knowledge. Their works have helped form a strong ontology of science – one that continues to be the subject of lively debate in the public domain.

These contributions are not aloof or 'pop psychology,' but rather a well-considered and articulated set of answers to fundamental questions that helps define the pursuit of science. They focus on creating an ontology of science – in other words, a study of the nature of being or existence of science, and how certain activities can be said to be science, and others not. Lipton [72] puts it this way:

> "Philosophers are not only interested in description: they are also interested in explaining why practitioners do what they do, and also in questions of justification, questions such as whether we are ever entitled to believe that a high-level scientific theory is even close to the truth. These are not the sorts of questions to which practitioners need have a ready answer."

Such study is not just to satisfy intellectual curiosities. In fact, the Royal Engineering Society in its compilation of papers on engineering philosophy [73] identify it as a critical field of study to bring the engineering profession into a more central position within mainstream society, rather than as a fringe-dweller in public life and public policy. Grappling with the role that the engineering profession currently provides, along with explicitly identifying the deeply seated competencies, identity, mental models, and value proposition of engineering are all key fronts in advancing the engineering profession. Crafting clear-cut boundaries help maintain the purity of professional standards, articulating strengths increases the influence of the engineering profession and articulating the unique role and ethos of the engineering discipline serves as an identity or persona that defines the type of people engineers aspire to be.

So, given the emphasis science places on articulating science ontology, can the same be said for engineering? 'Rarely' is the summary view of a number of writers [74], highlighting that such levels of reflection aren't common to many engineers, even though the techniques and thinking styles used by engineers and philosophers are in fact quite similar [75].

6.2 On the origins of the engineering discipline

In a fascinating piece designed to illustrate the differences between architecture and engineering, Davis [76] traces the two disciplines back to their roots. He illustrates how large-scale infrastructure projects, such as Michelangelo's Laurentian Library, were historically constructed by persons who were more considered artisans rather than architects or engineers, namely because the disciplines, yet alone the professions, were neither established or recognised. The activities now associated with engineering were in fact performed for several millennia without being called as such.

Eventually, the activity of design and construction evolved to the point where they were recognised as distinct disciplines. However, Davis points out that the early recognised architects were civilians who resided near large cities. In their activities, they engaged with the skills of other "allied arts" such as stonemasons, carpenters, and painters. Architects were first systematically recognised in 1671 when the French established the distinctive "Academy of Architecture."

In contrast, the idea of engineering grew almost independently from what Davis describes as the "sibling" of architecture, and started life as a recognised discipline first with the French *corps du genie*, a specialist military engineering unit established in 1676 [77]. The French army until that point had an engineering force among its ranks and were first called "engineers" in the sense of being soldiers associated with the "engines of war," such as catapults and siege towers. However, this new unit centralised the French's engineering skillset, which created a critical engineering mass. Within two decades, this move brought a great deal of additional military advantage to the French army by exploiting the technical skills of its engineering staff.

The unit was structured much like a school of masters and apprentices; however, the 'masters' were military Officers who, in turn, commanded craftsmen – enlisted soldiers who engaged in the trade of construction (at the time, the major activity of the engineering unit). It is this notion that gave rise to the idea of a *professional engineer* – someone who needed to study in order to become a leader of craftsmen. In the early 1700s, the corps developed a curriculum of engineering for those who wished to become Officers in this construction-focused unit. Davis suggests that the curriculum is in fact similar to those of the engineering schools of today, only differing in the scientific detail.

Davis observes that despite the almost parallel birth of the disciplines of engineering and architecture, their distinctions are rooted in their pedigree. Whereas architecture drew upon the skills of the civilian craftsmen, such as stonemasons, engineering was a competence fashioned in the demanding environment of warfare. It follows that where architecture was influenced by the civilian desire for aesthetics and the celebration of civic beauty, engineering's more pragmatic focus on factors such as reliability, speed and performance were cemented by the need to divert all efforts towards successful military campaigns and devising the best tools to help the army win. Even after several centuries, these distinctions – but also complementary emphases – are still readily identifiable.

It is out of this narrative that the modern concept of engineering was born. After a while, other countries started to copy the French model, even adopting the term "engineer" (a military term established by the French, along with *manoeuvre*, *bayonet,* and even *army*). The French also began to 'civilianise' the concept of engineering, establishing the *Ecole Polytechnique* (still in operation today) to teach engineering. Whilst the institution was initially set up to train military engineering Officers (students still wear the traditional military uniform of the day), with time, the educational model devised there would become the format used to teach the civilian population.

Davis [77] also highlights that civilian uptake for learning the engineering discipline was slow, noting that it wasn't until the 19th century that there was sufficient belief that engineering was "useful enough for non-military purposes." However, once this understanding and support for the discipline were sufficiently embedded, more and more trained engineers were able to carve out careers within the civilian populace.

6.3 The four manifestations of engineering

6.3.1 Discipline, profession, function and community

This historical view of engineering is more accurately explained as a history of the *discipline* of engineering. However, as Davis [76] points out, this is separate from engineering as a *profession*.

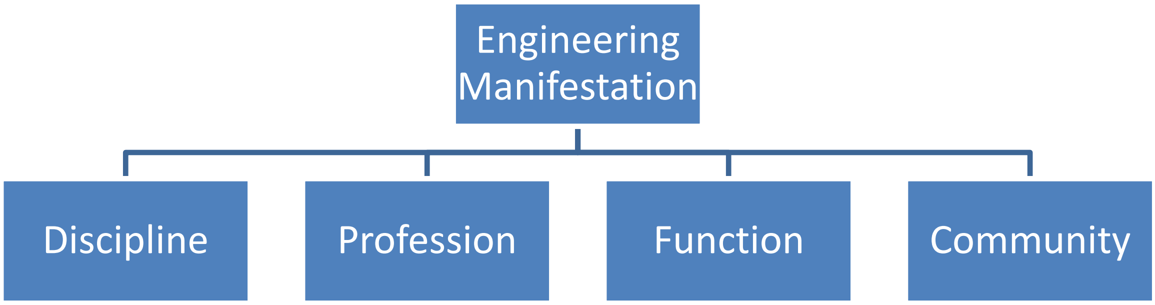

Figure 12: The four manifestations of Engineering

Whereas a discipline focuses on performing a certain craft with accuracy, intellectual rigor, with an explicit knowledge structure (effectively what can be *studied*), the concept of a *profession* extends this discipline to a level of recognition within a society where one is recognised as a practising expert in a particular field [78]. In turn, a profession is made up of people who practise a particular discipline.

This does lead to several other questions:

- How does one make a formal distinction between a professional engineer, a tradesperson, and a technologist, especially when many use the term *engineer* in some fashion?
- How does one differentiate between the function, the discipline, and the profession of engineering?

One of the immediate issues that confuse definitions of engineering is that of inconsistent terminology. Terms such as "locomotive engineers" and "Aircraft Maintenance Engineers" do not help – these types of tradespeople and mechanics have a strong relationship with technology, but are not professional engineers. Professional engineers, tradespersons, and technologists are all involved in the undertaking of technical pursuits. As Davis [76] puts it, they all contribute "to the life (and death) of technological systems, themselves relatively complex and useful artefacts embedded in a social network that designs, builds, distributes, maintains, uses and disposes of them."

However, whilst these types of personnel are all engaged in this context of technology, it is clearly evident that they are not engaged in the same type of endeavour, even if that social network's end goal is ultimately the same. In an attempt to reduce the confusion, some authors re-term these occupations as *technologists* [75, 76].

6.3.2 Identity of engineers versus technologists

Davis [79] illustrates how engineering became a discipline far ahead of it becoming a profession. He also points out, as described in the previous section, the evolution of certain crafts and trades into that of the professional engineer. However, Davis [80] is also at pains to make a very clear point about drawing a clear distinction between professional engineers, and those practitioners who have a common interest, such as technologists. He highlights three important distinctions concerning the engineering profession:

- Engineering does not equal technology; technology does not equal engineering
- "Tinkering" with technology does not equal engineering
- Possessing technical knowledge does not equal engineering.

In a detailed exposition, he makes the point that although engineering has a strong historical connection with the trades and other technologists, the role of engineering is unique and distinct. Further elaboration on more precise notion of engineering follows shortly, but Davis draws a clear line between engineering and technology, although limits the offer of what engineering is in the context of what engineering isn't.

However, this is not to say that engineering is separate from the wider technology community, as engineers are not the only ones who both have an interest and engage in this realm.

6.3.3 Engineering communities

Li Bo-cong [81] observes that the engineering community isn't just made up of engineers, but "other actors such as managers, technologists, and investors." Consider the construction of a building – the building is the object of the application of much technical knowledge and skill. Yet, its bringing to fruition (and further, its effective use) is not performed by professional engineers alone. The design, construction, and operational effort requires the use of project managers to direct the process of transforming a need or opportunity into a practical reality, investors and other financiers to pay, and tradespersons and other technologists, whilst perhaps not fully-versed in the engineering discipline, to use their talent and skill to take designs crafted by engineers and construct the vision. They are all actors whose interests have aligned around a certain benefit.

However, Davis [76] also demonstrates the reality that not all engineers are engaged in an endeavour of "designing [and] building." He states that some engineers "simply inspect; some write regulations some evaluate patents; some to reconstruct equipment failures; some sell complex equipment; some teach engineering." Yet, he also makes that point that "engineering is what engineers do in their capacity as engineers." Whilst the verb *engineering* implies a sense of doing something creative or constructive, it's clear that those who engage in Engineering (as a noun) need not be undertaking work according to this somewhat narrow interpretation. Engineers, operating in an engineering role, do engage in other high-order technical activities, whether it be employing the engineering ethos to protects society (as a regulator or inspector) or providing the right fit for a technology solution into a societal context (such as a sales engineer).

6.3.4 The engineering function

It's this broader concept of Engineering that gives rise to the idea of the Engineering Function in an organisation – an identifiable organisational unit or core capability that contributes to the broader operations and objectives of an organisation. This is particularly so if the organisation is not a 'pure engineering' (and particularly 'pure engineering design') firm and involves other sizeable functions and professions to achieve its objectives, such as a building construction firm who's core functions include purchasing, logistics, project management and construction.

It's a concept that writers in the engineering philosophy space offer little comment on (apart from the sense of 'engineering community'), although a number of authors discuss the structure of engineering teams, organisational structures, and the role of engineering in new product development [53, 67, 82, 83]. However, does the engineering function within an organisation merely exist only in the part of the organisational structure that is called "engineering," or can it exist and/or be recognised in other sections of an organisation in 'pockets'? It's this type of issue for which there seems to be little academic or research coverage.

6.4 What is engineering?

Having considered some of the factors that make finding a definition of engineering a less-than-straightforward activity, what are some of the accepted definitions of engineering?

Probably owing to the previous status of engineering philosophy, definitions of engineering are far and few between, although some professional associations provide definitions as part of their corporate literature.

Table 3: Various definitions of Engineering

Definition of Engineering	***Author***
"The transformation of the natural world, using scientific principles and mathematics, in order to achieve some described practical end"	Luegenbiehl [84]
"Engineering constitutes the systematic application of physical and natural resources combined in such a manner as to create, develop, manufacture and support a product or service which economically provides some form of utility to man".	Blanchard [67]
Engineering refers to the practice of organizing the design and construction (and [Vicenti] would add operation) of any artifice which transforms the physical world around us to meet some recognized need	Vicenti [85]
"Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience and practise is applied with judgement to develop ways to utilise, economically, the materials and forces of nature for the benefit of mankind"	Accreditation Board for Engineering and Technology (ABET) [86]
Engineers design, "build" (or, at least, manage the building), and otherwise contribute to the life (and death) of technological systems (that is, relatively complex and useful artefacts embedded in a social network that designs, builds, distributes, maintains, uses and disposes of them)	Davis [76]
The 'practice of professional engineering' means any act of planning, designing, composing, evaluating, advising, reporting, directing or supervising, or managing any of the foregoing that requires the application of engineering principles, and that concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment	Canadian Engineering Qualifications Board [87]
Business, government, academic, or individual efforts in which knowledge of mathematics and/or natural science is employed in research, development, design, manufacturing, systems engineering, or technical operations with the objective of creating and/or delivering systems, products, processes, and/or services of a technical nature and content intended for use."	National Research Council (USA) [80]

There emerge some common themes across each of the definitions.

1. **Knowledge base:** The focus on scientific and mathematical knowledge, often expressed as the 'forces of nature'
2. **Knowledge manipulation:** Having such baseline knowledge isn't enough, but rather is the base from which applied or problem-specific solutions can be found

3. **Unique skills sets:** Engineers can only apply this knowledge when they possess intrinsic traits, attributes, and skills such as creativity and communication
4. **Transformation:** Engineering is the business of transforming things from one type of use to another. This is reflected in its core methodologies and processes.
5. **Providing value:** Engineering must be focused on providing something that is of value, whether socially or economically.
6. **Social integration:** Some definitions, such as those of Davis and Lloyd also reflect on the interaction between the engineered system, and the social system which employs or interacts with that engineered artefact.

In essence, the concept of engineering comes down to a knowledge base or structure, a value-creating process, and a value-driven outcome of the engineering endeavour.

6.4.1 A service-centric view of engineering

One of the core ideas that this study is founded around is that of a 'service-centric dominant logic.' This logic, expounded in Chapter 7, is in contrast to 'product-centric' thought. Without pre-empting that discussion, it's not difficult to view many of the above definitions as phrases that mean *product development*.

However, there are some concepts alluded to that do go beyond a product-centric thinking style, such as Blanchard's "processes" and Vicenti's "operation." Davis [76], in providing a useful summary of what engineering is about establishes that "engineering design is central to understanding engineering … but [he] does not see how designing can be the (defining) function of engineering". He continues to state that "As I see it, there is no function that engineers, and only engineers, seem to perform (except, of course, engineering itself, which is what we are trying to define)."

However, it's evident that most definitions of engineering possess an implication – a tacit gravity – in favour of product-centric thought. It's a thought process that leads to planning frameworks and process methodologies that assume a product as the core output of engineering effort – frameworks such as the Systems Engineering lifecycle model.

6.5 An unsettled state

Whilst this reflection on engineering philosophy is illuminating, there remains the question: what is it that engineers fundamentally do? Given many writers assert definitions of engineering that pertains almost exclusively to the paradigm of designing and design, it begs the question: if engineering isn't exclusively about design, then *what* is it truly concerned with?

It's a question that's best considered after reviewing the case studies presented in the course of this study. As will be seen, there are many engineers, working in engineering functions, who don't *do* much design – yet, they are engaged in very meaningful engineering work. It's a quandary that presents a philosophical challenge, one that is picked up again in Chapter 26. There, a working concept of what engineering truly is concerned with is put forward in aid of creating a more congruent and amenable view of engineering in the in-service environment.

Part II

The conceptual building blocks

CHAPTER 7

The Service Paradigm

Seeing the World Through a Service Lens

7.0 Something has changed

Something has subtly – but strategically – changed in the aerospace and defence market: suddenly the industry finds itself no longer as just a product supplier, but as a service provider as well. No longer is the term “services” just an economics term that conjures up images of accountants or hairdressers – it’s something large manufacturers and system providers discard at their peril.

Much of the notion of Complex Integrated Solutions is built on the concept of *service*. However, what is “service”? Is it just about having someone by a phone 24/7 as a “service desk”? Or is there more to this concept that could revolutionise the way the aerospace and defence sector thinks? This section seeks to explore the transcendant nature of *service*.

7.0.1 What is service?

Both thought-leaders, as well as academic researchers, have been grappling with the economic, marketing and operational concepts of services for some time to advance the understanding of what services *truly* are. To better understand the term *services*, the concept can be broken up into several dimensions, including:

- the notion of a customer experience (Pine & Gilmore 1998) [88],
- the sense of customer satisfaction,
- a style of business operations (Fitzsimmons 2008) [89],
- a consumer line-of-business (Fitzsimmons 2008) [89],
- an industrial line-of-business (Pawar et al) [90],
- a definition of a type of economic activity (OECD) [91],
- a dominant logic about how organisations think about themselves and how they relate to their customers (Vargo & Lusch) [92],
- a business model,
- a basis of business strategy.

This chapter looks extensively at service as an industrial line-of-business, a business model, a basis of strategy, a dominant logic for organisations, and extends these concepts out deeper into the industrial realm through the concept of *servitization* in the next chapter.

At its core, the concept of *servitization* focuses on manufacturing firms and an ongoing trend for their adoption of service offerings alongside, and in some cases, in lieu of a product portfolio. Servitization is somewhat of an umbrella of linked and related, albeit often independent, fields including Product-Service Systems, Integrated Solutions, and Complex Engineering Service Systems.

It's all fascinating material. But to truly appreciate it, it's important first to get a handle just what a service is, which first requires getting a handle on its seeming counterpart: product.

7.1 What is product?

It's important to consider the notion of services simultaneously with products, as much of the literature expresses the notion of service in terms of, or with respect to, products and goods. Vargo & Lusch [92] make the point that much of the marketing literature discusses economic activity primarily from a goods-centric worldview or "dominant logic"[8]. This perspective is elaborated on shortly, but in short stipulates that the main unit of economic activity that defines local, national and international trade is the exchange of goods for reward, namely money. As discussed in Chapter 6, much of the engineering management literature is also very heavily skewed towards product development, with the role that engineering plays, and the value it creates, more-often-than-not expressed in terms of physical products. However, as is discussed shortly, a dominant logic in marketing that is services-centric is emerging and is argued by the Vargo & Lusch as being more representative of current mega-shifts in the global economy towards a services-based economy.

Because much of the literature is expressed in terms of goods only, it's not a straightforward task to construct a clear definition of goods, nor is it an easy task to find definitions that expound the notion of what goods are beyond being just 'things'. Their tangibility and prevalence in society have most likely made it such that we don't often need such definitions. Simple dictionary definitions explain products as articles or substances that are "manufactured or refined for sale", as "something produced by human or mechanical effort" to "a thing produced by labour or effort". Whilst entirely true statements, they don't reveal more meaningful attributes about what products are.

One more highly recognised definition within the academic community is that goods are "a tangible commodity manufactured to be sold … and capable of 'falling on your toe'" [93]. Vargo & Lusch also provide their own definition, defining services as "things … embedded with utility and value during the production and distribution process." Perhaps one of the more fuller definitions comes from the American Marketing Association which defines products as:

> A bundle of attributes (features, functions, benefits, and uses) capable of exchange or use; usually a mix of tangible and intangible forms … It exists for the purpose of exchange in the

[8] Vargo & Lusch explain it best when they describe the notion of dominant logic, or worldview, as being "never clearly stated but more or less seeps into the individual and collective mindset of scientists in a discipline. Predictably, this requires viewing the world at a highly abstract level." In other words, it is the overarching, assumptions, beliefs, and mental models which professionals in a given discipline adopt, often unknowingly and automatically, which guides how they perceive, interpret, understand and respond to certain phenomena such as events, information, and personal experience.

> satisfaction of individual and organizational objectives. Occasional usage today also implies a definition of product as that bundle of attributes for which the exchange or use primarily concerns the physical or tangible form, in contrast to a service, in which the seller, buyer, or user is primarily interested in the intangible [94].

7.2 What is service?

Despite the many variants of the use of the term *service*, in the economic activity and marketing space, it tends to be associated with the notion of activity, value proposition, and organisational capability.

7.2.1 An economic concept

The OECD states that services are “a diverse group of economic activities not directly associated with the manufacture of goods, mining or agriculture [and] they typically involve the provision of human value added in the form of labour, advice, managerial skill, entertainment, training, intermediation and the like [95].”

Quinn, Baruch and Paquette [96] extend this theme into the intangible realm, describing services as “all economic activities whose output is not a physical product or construction, is generally consumed at the time it is produced, and provides added value in forms (such as convenience, amusement, timeliness, comfort or health) that are essentially intangible concerns of its first purchaser”. Vargo & Lusch [92] offer that *services* are “the application of specialised competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself”.

Again, the American Marketing Association, through its extensive definitions publication, offers a series of definitions. In the 1960s, it stated that services were:

> “activities, benefits and satisfactions, which are offered for sale or are provided in connection with the sale of goods [97].”

By 1995, however, it had changed that to the notion that *services* are actually:

> “products, such as a bank loan or home security, that are intangible or at least substantially so. Service products are often difficult to identify, because they come into existence at the same time they are bought and consumed. They comprise intangible elements that are inseparable; they usually involve customer participation in some important way; they cannot be sold in the sense of ownership transfer; and they have no title [94].”

They continue, explaining that in today’s economy, such “products” are often found in a hybrid form, with the term “goods or services” used to classify offerings that “are partly tangible and partly intangible”. The AMA also counts as a secondary use of the term *services* as “activities performed by sellers and others that accompany the sale of a product and aid in its exchange or its utilization (e.g., shoe fitting, financing) [94].”

7.2.2 Service characteristics

Services also have several unique identifying attributes about them. Fitzsimmons [89] explains how service operations tend to be viewed from an open systems perspective in that the customer is present in the delivery and provision of the service. This contrasts with manufacturing operations that are isolated or "buffered" from the customer by an inventory of finished goods. He goes on to identify five distinctive characteristics of service operations that include:

- Customer participation
- Simultaneity
- Perishability
- Intangibility
- Heterogeneity.

With products, customer participation tends to be limited to that of a passive buyer (depending on the context), whereas services require a more engaged and proactive customer working with the service provider, often (but not always) at the service provider's facility. The provision of customer knowledge, experience, motivation, and even honesty affects the performance of the service system. Fitzsimmons gives the example of an education service where the student's own effort, motivation and contribution largely determines the outcome of the education service. Likewise, with an auto-repair service, the customer can affect the outcome of a vehicle's servicing by providing details of known faults and driving patterns. Normann & Ramirez [98] extend this idea to by stating that "the key to creating value is to co-produce offerings that mobilise customers".

Services are created and consumed simultaneously and thus cannot be stored. This is in contrast to the inventory method used for products – a useful strategy, as Fitzsimmons puts it, because "as a closed system, inventory decouples the production system from customer demand [89]". However, services are open systems, and thus the service provider must use other techniques to optimise the amount of service capacity, facility utilisation (if required), effective use of idle-time, profitability, and customer satisfaction levels as services are simultaneously produced and consumed. Quality is also more difficult to control; whereas defect products can be tested and rejected at the end of a production process, defective service has to be addressed in a concurrent way.

It follows that services are thus perishable if they are produced and consumed simultaneously. An empty airline seat or an unoccupied hotel room are revenue opportunities that are lost forever. To compensate, service firms are driven to manage demand closely, whether it be increasing resources at predicted peak times (such as lunch and dinner times in a restaurant), or through using market-based means to 'smooth over' demand, such as offering off-peak pricing to allure customers to utilise services at non-peak times.

Whilst products are immediately discernible as objects, can be held, as well as touched, services are less readily recognisable and can be far more difficult to describe. Interacting with a product is generally a straightforward proposition, whereas interacting and 'trying out' something that doesn't yet exist is difficult if not impossible. The idea of products also permits customers to return the item if it is defective or otherwise doesn't live up to expectations. Services, however, cannot be 'returned'. This has significant implications for service firms where the customer must rely on the reputation and previous performance of the firm.

Services are also very heterogeneous in nature – that is, it can be difficult to create a standard service, especially when it is responding to the individual needs of customers. When considering the intangible nature of services, combined with the customer participation in services, it becomes apparent that different customers will experience a different service. Fitzsimmons notes that in services, work tends to be more orientated towards people, rather than objects (this is certainly true in consumer businesses – application to the industrial sector will be discussed shortly).

Services are also defined in terms of their non-ownership characteristic. Unlike with product-based transactions, purchasing a service does not involve the transfer of ownership; rather, a conveying of benefits. The notion of "ownerless consumption" can be troublesome for some businesses [99].

7.2.3 Beyond an economic activity

Many of these definitions deal with service as a verb, describing services in terms of action, delivery, process and activity. These definitions are also in contrast to the notion of *product*: something that is storable, a static entity until engaged in an economic transaction and, within reason, less-perishable (i.e., many products can sit on a shelf for a long period of time before been sold, although there generally is a limited economic life).

The context, too, is important. The American Marketing Association views services in light of selling goods, whereas OCED sees services as a distinct and separate (although not entirely independent) stream of economic activity to the sale and exchange of goods. Fitzsimmons [89], Baines et al [99], and the AMA [94], however, are pragmatic about the sales of products and services, and that usually, any 'offer' to a customer involves both.

However, this notion of service isn't restricted to the idea of activity (service as a verb); it also extends to the notion of service as a unique value proposition and something that is has a transcending meaning. Thus it is important to gain an understanding of service as a noun in the context of a *services-centric view of marketing*.

7.3 From a goods-centric view to a services-centric view

7.3.1 What is marketing?

To understand a services-centric concept of marketing, it's important first to establish what marketing truly is, especially when it can be easily confused for a term describing advertising campaigns or persistent sales calls.

In this context, it is referred to in its proper and formal study, particularly as an organisational discipline and function. Kotler [100] refers to marketing as "identifying and meeting human and social needs", and more specifically "meeting needs profitably". The American Marketing Association [94] asserts its perspective on marketing as "an organisational function and a set of processes for creating, communicating and delivering value to the customer and for managing customer relationships in ways that benefit the organisation and its shareholders".

Taken to a global context, Bradley [101] defines international marketing as the process of "identifying needs and wants of customers in different markets and cultures, providing products, services, technologies and ideas to give the firm a competitive marketing advantage, communicating information about these products and services, and distributing and exchanging them internationally through one or a combination of foreign market entry modes". But perhaps the most revealing definition is that of Barabba [102] who very simply states that marketing is "an organisational state of mind", referring to the notion of how the organisation sees itself in relation to its customers and the value that it brings.

The notion of marketing in this study refers particularly to the idea of researching a current or potential customer's need, understanding that need sufficiently to synthesise an offering (product, service or both), communicating that offering into the marketplace, and managing the expectation of customers through the delivery of that offering – all in the context of that organisation's strategy. It is a sometimes subtle but very real organisational activity that positions a firm for winning business – the activity that the sales function performs. As will be made apparent in subsequent sections, understanding this process, both as a linear progression, and as an iteration, underpins the logic behind a service-centric view of business offerings and operations, as well as the core reasoning for specific manifestations of a service-centric approach, explored later.

7.3.2 Product-centric thought

So far, *services* have been examined in terms of activity, and as a 'thing' that conveys some sort of usefulness, even if it that 'thing', as well as the benefit incurred from that 'thing', is intangible.

Over the space of several years, a series of publications from the marketing community expanded on the notion of service as being more than an activity, but something more transcendent in nature. Vargo & Lusch plot the major changes in marketing logic and thought over almost a century, and highlight work by Shostack [103] as an inflection point whereby services marketing became an established subset of the marketing discipline rather than its background of a pure product-driven paradigm.

Dixon [104] also raised the issue, pointing to the weaknesses such a dominant logic had with services, Rust [105] also continuing the theme, pointing to the almost illogical stance taken in the marketing community that somehow services were a "niche field" and were often defined in terms of differences with products. He argues that this perspective is unhelpful for understanding services, and also has the potential for blocking a more thorough understanding of the idea of marketing itself. This culminated in a statement by Parvatiyar et al. [106] that "the sacred cow of exchange theory" – the notion of exchanging goods for financial gain – had to be done away with. This is a cornerstone of an alternate dominant logic proposed by Vargo & Lusch.

To further understand this contention, it's important to consider the key attributes of such a goods-dominant logic. Vargo & Lusch identify five key propositions of such a worldview:

1. Making and distributing 'things' to be sold is the core aim of economic activity
2. To be sold, these things must be embedded with utility and value during the production and distribution process and must offer the consumer superior value in relation to competitors' offerings
3. The firm should set all decision variables at a level that enables it to maximise the profit from the sale of output
4. For both maximum production control and efficiency, the good should be standardised and produced away from the market (customers)

5. The good can then be inventoried until it is demanded and then delivered to the consumer at a profit.

They also identify other key attributes of a goods-centric worldview, including the idea that value is determined by ownership (i.e., the value of a product is in owning it), and that the customer kept at ‘arm’s length’ from the value-production process in order that the process may be as efficient as possible.

7.3.3 Service-centric logic

It’s important to point out that a goods-centric view is not without merit: clearly, the selling, buying and using of products is of key importance in any economy. However, it is a worldview that leaves very little room for understanding how services fit into the scope of defining and creating value for the customer through solving their needs. Gummesson [107] points out that “customers do not buy goods or services: they buy offerings which render services which create value … the traditional division between goods and services is long out-dated. It is not a matter of redefining services and seeing them from a customer perspective; *activities render services, things render services*. The shift in focus to services is a shift from the means and the producer perspective to the utilisation and the customer perspective”.

To redress this seemingly unsettled notion of understanding products, services and value, Vargo & Lusch detail a comprehensive worldview that is services-centric in nature. They characterise this worldview through eight key fundamental principles of the service-centric dominant logic, principles that are also juxtaposed with a goods-centric worldview in

Table 4. The eight key principles are:

- The application of specialised skills and knowledge is the fundamental unit of exchange
- Indirect exchange masks the fundamental unit of exchange
- Goods are distribution mechanisms for service provision
- Knowledge is the fundamental source of competitive advantage
- All economies are service economies
- The customer is always a co-producer
- The enterprise can only make value propositions
- A service-centred view is customer orientated and relational.

Table 4: Goods-versus-services dominant logic [92]

	Traditional Goods-Centred Dominant Logic	Emerging Service-Centred Logic
Primary Unit of Exchange	Goods are exchanged for monetary value	An acquisition of the benefits of specialised competencies or services
Role of Goods	Goods are the end-product	Goods are transmitters of 'embedded knowledge' or functionality when used
Role of Customer	The customer is the recipient of goods, and marketing researches and promotes to them	The customer is a co-producer of service, and marketing involves interaction with the customer
Determination & Meaning of Value	Value is determined by the producer	Value is perceived and determined by the consumer on the basis of "value in use".
Firm-Customer Interaction	Customers transact with a firm	Customers are active participants in relational exchanges
Source of Economic Growth	Wealth consists of owning, controlling and producing resources	Wealth is obtained through the application and exchange of specialised knowledge and skills

This alternate worldview seeks to reposition the idea of the fundamental purpose of economic activity as moving away from the exchange of 'things', to the provision of benefits in return for financial reward. Customers are not purchasing products, but rather the benefit that products and/or services (verb) can provide for them. It also reflects an ongoing economic reality in that over 70% of the economic activity in OECD countries is services-based [95].

It's also a view that does not dispose of the need for products but rather reinterprets the role of products as purveyors of 'embedded knowledge' that deliver benefits ("services"). Thus, products effectively become a subset of services. An example is found in Nonaka & Takeuchi [108] with a domestic bread-maker appliance, a device designed to produce bread that a baker would normally produce. Nonaka & Takeuchi depicts how Japanese firms carefully studied the actions and techniques of several master-bakers to gain a better understanding of how these actions could be mechanically replicated through a machine. The product is not merely a commoditised device but is, in fact, a unit in which engineers and designers have 'embedded' the skills and techniques of a service professional (in this case, a baker) which is now modularised, automated, and transportable (and, ideally, also profitable). What the customer is purchasing is the benefit of this embedded skill and knowledge (hot fresh bread at home), rather than a physical artefact. It's a point that also illustrates other key notions of the services-driven view of products, in that their value is in their use, that than their ownership.

Another key notion of the emerging services-centric view is that of customer focus. Vargo & Lusch make the argument that "over the past 50 years, marketing has been transitioning from a product and production focus to a consumer focus and, more recently, from a transaction focus to a relationship focus." Another related work by Hauser and Clausing [109] describes how this approach is very similar to the pre-Industrial Revolution concept of providers been close to their customers, and how such relationships saw the offering of customised services. They pose an example of historical knight armourer. If a knight was seeking new armour, they talked directly to the armourer and collaborated on what exactly was required, to which the armourer would then construct a tailored solution. “Marketing, engineering and manufacturing were integrated – in the same individual”.

It is also a view that focuses on the firm establishing value propositions and is based on resource-based views of the firm (Hunt) [110], competitive advantage theory (Porter) [111], and core competency theory (Prahalad & Hamel) [112]. They state four disciplines that an organisation driven by a service-centric worldview will seek to achieve:

- Identify or develop core competencies, the fundamental knowledge and skills of an economic entity that represent competitive advantage
- Identify other entities (potential customers) that could benefit from these competencies
- Cultivate relationships that involve the customers in developing customised, competitively compelling value propositions to meet specific needs
- Gauge marketplace feedback by analysing financial performance from exchange to learn how to improve the firm’s offering to customer and improve firm performance

It’s important to remember that a goods-centric view isn’t necessarily ‘bad’, but rather is simply incomplete. It also doesn’t account for the extra complexities that services tend to induce, such as working with the customer – an interaction which can be perceived in inhibit efficient production of value.

7.4 How does this fit in an industrial context?

Henry Ford once made the assertion [113] that “a business absolutely devoted to service will have only one worry about profits … they will be embarrassingly large” – an ironic statement from a man whose manufacturing business was product-centric. It serves to point out that a services-centric dominant logic is not incompatible with a manufacturing operation. The meaning of “services” in this context is a transcendent one in that there are two meanings. The verb “service” describes the process or activity of delivering a service, whereas the ‘higher’ meaning in the noun “service” refers to the fundamental shift in worldview about how businesses relate to their customers.

The question remains, however: how does this services-centric worldview apply in the industrial services space? How is the concept applied, expressed and manifested in an environment in which complex technical innovations (often in the form of products) are still vital to providing value and delivering on customer need? An overarching answer is found in the notion of *servitization*.

CHAPTER 8

The Industrial (Services) Revolution

The March to Servitization

8.0 A revolution birthed

With the increase of globalisation in the 20th century came an increased focus on placing industrial-scale production efforts in lower-cost locations. Successive commentators and analysts have passed judgement on the future of manufacturers in higher-cost locations – namely Western countries – a judgement that has triggered much soul-searching and strategic debate about the future of a domestic manufacturing base, as well as what current manufacturers can do to survive.

It's from this context that the concept of *servitization* emerged.

8.1 The servitized economy

The term *servitization* emerged from the field of competitive manufacturing strategy and was originally coined in 1988 by Vandermerwe & Rada [114]. They define servitization as:

> "market packages or 'bundles' of customer-focused combinations of goods, services, support, self-service and knowledge."

Their research focused on trends occurring within a number of industries (both manufacturing and non-traditional production) and how firms were changing their core offerings to the market to include a strong service element.

It is considered an important topic as it relates to how manufacturing sectors are evolving to maintain a competitive edge, and in some cases, ensure their long-term survival [99]. Authors make mention that the growth of services has been one of the major trends in recent years, with the change in the structure of national economies making servitizing a critical strategy for business success [99, 115]. While traditionally society has lived in a product-centric economy – especially as a result of the Industrial Revolution – it is almost universally accepted the global economy has transitioned to a service-dominated economy [91]. OECD data indicates that by 2002, the share of the service sector amounted to about 70% of total value added in most OECD economies, and that it has experienced significant growth ever since the 1970s [95]. Clearly, products have not disappeared, but the data makes it clear that it is no longer the primary source of economic activity for many societies.

In pioneering the term servitization, Vanderemere and Rada's article has become a widely-cited reference in the study of the service phenomenon in the manufacturing sector. Since then, several studies have emerged focusing on descriptive and exploratory examples and case studies of servitization, the drivers for servitization, categorising the different forms and expressions of servitization, the challenges faced in adopting a servitized strategy, and how there is a lack of detailed research and knowledge on the subject.

A raft of new and expanded definitions of servitization have also been put forward, especially in the context of manufacturing firms. They include that *servitization* is:

- "A trend in which manufacturing firms adopt more and more service components in their offerings"[116]
- "The emergence of product-based services which blur the distinction between manufacturing and traditional service-sector activities" [117]
- "Adding extra service components to core products" [118]
- "An integrated bundles of both goods and services" [119]
- "Any strategy that seeks to change the way in which a product functionality is delivered to its markets" [120]
- "A change process wherein manufacturing companies embrace service orientation and/or develop more and better services, with the aim to satisfy customer's needs, achieve competitive advantages, and enhance firm performance" [121]
- "The innovation of an organisation's capabilities and processes to better create mutual value through a shift from selling product, to selling Product-Service Systems" [122]
- "The process of creating value by adding services to products." [99]

Table 5: Refined value propositions [123]

Industry	Traditional Product	Value Added Service	Traditional Value Proposition		Solutions Value Proposition
Truck manufacturing	Trucks	Finance Servicing	'We sell and service trucks'		'We can help you reduce your lifecycle transportation costs'
Aerospace Components	Aerospace fasteners	Application/design support	'We well high-performance fasteners'		'We can reduce your operational costs'
Utilities	Electricity	Energy asset maintenance	'We provide electricity reliably'		'We can help you reduce your total energy costs'
Chemicals	Lubricants	Usage and application design Lubricant analysis	'We sell a wide range of lubricants'		'We can increase your machine performance and uptime'
Pharmaceuticals	Drugs	Product-support Outcomes driven information database	'We sell pharmaceuticals'		'We can help you better manage your patient base'

There emerges a key set of themes from these definitions. Whilst the original research piece (Rada) was focused more on consumer businesses (e.g., banks), much of the more recent material has focused on industrial applications and solutions. Many of the propositions put forward tend to state that servitization is simply the process of adding services to existing products – in itself a legitimate service strategy. Key to this theme is the idea of redefining the value proposition to a customer. No longer, for example, would a truck manufacturing firm be merely selling trucks, but when combined with other services, becomes an overall Service of helping customers reduce their lifecycle transportation costs.

Embedded in this logic is the increasing emphasis on functionality delivered to the customer, versus mere ownership. As highlighted in the previous section, under a Service paradigm, value is not defined by the exchange of money for product, but rather for the value in use of the product of service. This is also known as the *functional product* approach and is described in more detail shortly. To achieve this goal, there is a renewed focus on the need for a modification or enhancement of an offering to solve a customer's need. It is this logic that lends itself to the idea of supplementing products with services as an outwards form of servitization.

However, there is also a growing body of thought that emerges as one looks further of servitization being both about the modification of an offering to customer, as well as the process or ambition of organisational transformation towards a different state of order (e.g., no longer 'just' a production organisation, but rather a service or solutions organisation). Some manufacturing firms may find just modifying the offering as being sufficient; however, many authors make the suggestion of a 'whole-hearted' change [98, 124].

8.2 Examples of servitization

A leading category of literature on servitization is case studies and examples of a servitized industrial approach. Leading examples are taken from the rail, aerospace, training, IT, communications, power-generation and construction sectors. Among the common examples are:

- Rolls Royce with their Power-by-the-Hour service package [115, 125]
- Thales, with their moving up the value chain adding pilot training services to their portfolio of flight-training simulator systems [126]
- Alstom with instances of integrated bundles of services to operate and sustain train networks [126]
- Nokia, with an emphasis on providing turnkey communication network solutions to mobile carriers in North America [127]
- Fujitsi Services in providing a proactive IT helpdesk solution [128]
- IBM with its consulting arm that integrates systems from various vendors (and not just itself) to provide a solution to a client's needs [129]
- ABB with turnkey power generation systems and solutions; and
- Xerox with a shift in its business model from being a printer/photocopy manufacturer, to a provider of fixed-per-copy printing services [130].

8.3 Drivers of sevitization

The servitization of manufacturers is often presented against a backdrop of manufacturer attitudes towards services. Some authors suggest that not only has the concept of services been viewed with indifference, in some areas they're even considered a "necessary evil" [33, 115] or a "harmful necessity" [131]. Such studies suggest a manufacturer attitudes' are such that services are a low priority for the business, and are only considered because that represent "order winners." This is a strong theme underpinning of servitization – it's not simply adjusting what manufacturers offer, but adjusting the manufacturing organisation itself to value services and see them as a core part of what they do.

The drivers for servitization are another key theme that emerges from the literature. Oliva & Kallenberg [132] identify three key drivers that are confirmed by other authors – economic arguments, customer demand, and the push for a firm's competitive advantage.

8.3.1 Opportunities for more revenue

Many researchers pose the economic benefits of servitization for four main reasons. First, the increase of revenue over the lifecycle of a product is reported to be substantial by a number of authors – over 50% of revenue opportunities on many aircraft programs are in the post-sale environment [132-134]. Secondly, there is some evidence that for some industries higher margins can be made on services when compared to products [135]. Third, services are seen as providing a more stable source of revenue, especially when considering economic, investment and equipment-purchasing cycles [96]. Finally, building on point three, services present an opportunity to 'smooth over' cash flow of the manufacturing firm due to both the long-life and low-turnover of the *installed-base*[9].

Wise & Baumgatner [127] specify the ratio of installed-base-to-new-units (i.e., the number of existing in-service products compared to new ones that have been ordered) is in the order of 150 to 1 for commercial aircraft, 22 to 1 for train locomotives, and 30 to 1 for tractors. Any opportunity to extract additional revenue from this existing pool of installed-base units is likely to present a significant revenue advantage compared to focusing just on product sales. This is especially true for a number of manufacturing firms where profits in the product-only sector of their business are continuously been eroded away [90]. This is why the spare-parts business has been popular with aircraft manufacturers like Boeing [115, 127, 133, 134]. It is this logic that has driven concepts like Through Life Management.

8.3.2 Opportunities for new business models

Another key driver of servitization is the opportunity presented in demand from customers for more integrated offerings. This demand emerges from a desire by customer organisations to outsource non-core capabilities of their business, and focus on what they do well at [129, 136]. In addition, the increasing complexity of some products makes outsourcing their support or operation an attractive proposition [129, 133, 134].

Galbraith [129] states the example of mobile phone deregulation in Europe and North America where several new upstart mobile phone network providers launched. However, as their skill-set was in

[9] The unit of major products that are placed and operating within the customer organisation, such as train vehicles, aircraft, computer terminals, power-generation units, etc.

marketing, and not communications engineering, went to the major communication equipment manufacturers to design, construct and operate the phone network, whilst the carrier focused on customer service. Organisations like Siemens and Alactel responded by saying “we design and build [communication and network] switches, not networks.” Nokia, on the other hand, saw an opportunity and mobilised itself to develop new organisational capabilities to deliver an integrated solution for their carrier customers. This approach led to the company becoming number one in mobile telecommunications systems and networks in the 1990s.

8.3.3 Competitive advantage

Researchers pose another reason for the push for servitization – developing a competitive advantage (a concept detailed earlier). Heskett et al [137] make the argument that because services are far more labour dependent, the offering becomes far more difficult to imitate, giving the firm an advantage over other firms. In addition, as illustrated with the Nokia example, the provision of services and integrated solutions can open up new opportunities and give a manufacturer an advantage over its competitors based on the strength of those services.

8.3.4 Growth adjacent to the core

Whilst not strictly part of the servitization narrative, the drive for a more service-driven approach can also be described as seeking ‘growth adjacent to the core.' This is a concept originally described by Chris Zook in his book *Beyond the Core* [138] where he explores firms seeking growth in areas that sit adjacent to their core capability and key business focus. The book cites examples such as IBM and how it moved from selling software and hardware, to selling services – operating from a common corporate capability base of technology expertise, but instead deployed in other ways. Servitization is effectively an ‘adjacency growth strategy’ for high-tech and manufacturing firms seeking to exploit their corporate knowledge, skill and capability base for further revenue, and potentially stave off disruptive market forces that could be fatal for such firms.

8.4 Classifications of servitization

There is a number of alternative, albeit complementary views about the various types, expressions, and manifestations of servitization.

Oliva & Kallenberg [132] propose a framework as a research design aid which they used in identifying where an organisation’s product-service offering was initially positioned. Figure 13 illustrates the simple concept of a firm’s offering to the market as being somewhere between a product with “add-on” services, right through to services been so central to the offering that tangible products are considered an “add-on.”

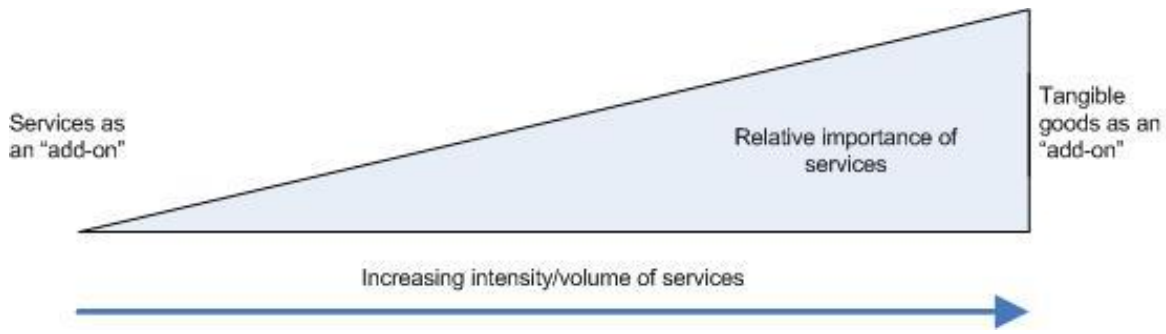

Figure 13: Product-service continuum [132] (Oliva & Kallenberg 2003)

Kotler [100] proposes a similar classification scheme, termed the "service mix" – as opposed to the *marketing mix*, a well-known term in the marketing profession – and identifies five types of offering:

1. Pure tangible good
2. Tangible good with accompanying services
3. Hybrid
4. Major Service with accompanying minor good and services, and
5. Pure service.

Mathieu [139] and Cova et al [140] categorises service offerings from manufacturers as:

1. services supporting a product;
2. services supporting the customer's activities, and;
3. services that support the stakeholder network surrounding the client.

This arrangement is of particular interest and raises an important point – the difference between services that support a product, and services that support a customer. Brax [124] makes the point that the two streams are different, even though they are often talked about as the same thing. Dainty [115] also reflects on this point, suggesting this is a key issue in developing a proactive customer orientation within a service provider.

Based on the examples and case studies reviewed, it becomes apparent that there is no one-sized approach to describing and classifying servitization. Some authors suggest that it's incredibly difficult to apply frameworks and strategies from one industrial sector to another [115] based on the variability between contexts. Even between organisations in the same industry, different strategies will lead to different offerings, some more servitized than others.

8.5 Business models

They way these offerings are delivered has also been of interest to researchers. Wise & Baumgartner [127] identify four forms of business models that manufacturers have used when moving "downstream" towards the customer, namely Embedded Services, Comprehensive Services, Integrated Solutions, and Distribution Control.

8.5.1 Embedded service model

The Embedded Service model reflects observations made in Nonaka [108] (and mentioned above) about embedding services of a professional into the product itself (in that case, the skill-set of a baker into a home bread-making machine). Similar concepts exist, most notably the concept of functional products [141]. Functional products are defined as "products that comprise combinations of 'hard' and 'soft' elements' … comprising hardware combined with a service support system". The concept is heavily modelled on experiences with Rolls Royce and echoes the product-service approach that is described shortly.

8.5.2 Comprehensive services

This approach sees manufacturers use their position as product suppliers to "launch suites of services for customers." While not always sold alongside a product, or to support a product, these services that supplement and support customer activities. They state an example of General Electric's train locomotive division providing a series of outsourcing activities, including running maintenance facilities, providing scheduling services, undertaking refurbishments and even working with another supplier to improve track utilisation. In the aerospace context, this form of business model is becoming increasingly popular, with organisations like Boeing taking on higher levels of services that tend to be either isolated from their own product or are more ad hoc – for example, non-integrated maintenance service contracts and upgrade projects [133, 134].

8.5.3 Integrated Solutions

Integrated Solutions describes where a manufacturer combines products and services into a "seamless offering that addresses a pressing customer need." They explore the example of Nokia and how they responded to an opportunity to provide turnkey solutions for mobile carrier network expansion. They assembled a portfolio of products including transmission equipment and switches, and combined it with a range of services, including planning, design, construction and maintenance, to help their network carrier customers to expand rapidly in the early 1990s.

8.5.4 Distribution control

Whist claimed to be a service business model, Distribution Control is a marketing approach to link manufacturing operations with the end-customer. It does not explicitly provide any benefits for the customer, only as a way of controlling the delivery of end-product. The authors state an example of Coca-Cola taking over the distribution of its product. Instead of relying on warehousing and distributors, they elected to control exactly how Coke was sold through its various outlets (e.g., supermarkets, vending machines, etc.), the benefit been the company been able to control the end-price of its product.

8.6 Going deeper

While these authors have identified useful classification schema, what has been reviewed only pertains to the basic overview of offerings that manufacturing firms make, as well as some of the business models used to deliver these offerings. However, other schema have also been developed, some of which is described shortly under organisational considerations. There are, however, gaps, especially when compared to Chapter 4 which identifies a number of dimensions that exist in the aerospace and defence sustainment and support field. Whilst some of these aspects from Chapter 4 can be clearly recognised as fitting either the Comprehensive Services business model or the Integrated Solutions model, considerations such as the 'depth' of the service, the provider of the service, and the duration of the service still find no clear 'home' in these classifications.

This is why attention must be diverted to understanding the concept of Integrated Solutions in more detail.

CHAPTER 9

Getting Down to Business

Integrated Solutions

9.0 Tautology and terminology

The concept of servitization encapsulates the strategic, service-driven approach of a manufacturer and the offering that it presents to the market. It can range from providing new, standalone services unrelated to an existing product line, through to providing services for or with a competitor's product, through to adding peripheral services to its own portfolio of products, through to the provision of bundled packages of products and services, all delivered in the one deal. Servization also conveys the notion of the manufacturer, as an organisation, undergoing a transformation in its corporate makeup and restructuring itself to become more service-orientated – irrespective of the offering that it presents.

Integrated Solutions stand alongside several other terms that describe a similar category of business model, Product-Service Systems [142], Complex Products and Services (or *CoPS*) [126, 136], The New Service Model [143], and Integrated Solutions [122, 129, 136, 144]. Not all of these concepts have their genesis in servitization; however, they're each conceptualisations or manifestations or a servitization strategy. Many of these concepts are initially considered separately, before finer issues, generally common across each concept, are examined in more detail.

9.1 Product-Service Systems

Product-Service Systems are argued to be a special case of servitization [99] and is a specific manifestation of more integrated approach consistent with a hybrid or integration of products and services. As the name suggests, Product-Service Systems are offerings in which services are bundled – and more importantly, integrated with – products to provide enhanced benefits to a given customer.

9.1.1 Definitions

Antonacopoulou et al. [143] and Baines et al. [99] point out that much of the research has come from the USA and Western Europe, focusing on studies of traditional manufacturing-orientated firms adopting a more servitized approach. Many of these studies have attempted to form a definition of PSS, some of which are found in Table 6. Some authors have identified that, like the field of servitization, there are no widely accepted definitions of PSS [115, 145]. Whilst each definition has their own nuances, there emerge several key themes.

Table 6: Common definitions of Product-Service Systems

Definition	Author
"A product-service system is a system or products, services, networks of "players" and supporting infrastructure that continuously strives to be competitive, [and] satisfy customer needs …"	Goedloop [93]
"An innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands"	Manzini [146]
"A PSS consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs"	Brandsotter et al. [147]
"Product-Service Systems may be defined as a solution offered for sale that involves both a product and a service element, to deliver the required functionality"	Wong et al. [148]
A PSS is an integrated product and service offering that delivers value in use	Baines et al. [142]

9.1.1.1 Meeting customer needs

A PSS must be focused on meeting customer needs and providing value to them through the functionality contained in the PSS. The core logic of such an approach is not just providing a collection of various elements that are 'added on', but rather all decisions in the design of the PSS must be driven by the needs of the customer. Adding to this logic is that there exists and intentional combination of various elements (including products, services, information, management and infrastructure) into an offering to a customer.

9.1.1.2 A system

A Product-Service System is an offer that involves selling more than just the sum of the parts – each of these elements work together to deliver something of benefit to the customer. Something that is not immediately picked up by the term "Product-Service Systems" is critical importance (in many instances) of physical non-product entities such as infrastructure. That is, the infrastructure is not the product containing the functionality to be supplied to the customer, yet the infrastructure, such as support and service operations facilities, is a critical element of the system, without which the overall system would not function as intended.

9.1.1.3 Corporate strategy

The definitions also allude to two corporate strategy aspects of Product-Service Systems. They're developed as broader themes through the rest of this study, but in brief, PSS also represent:

- A market strategy position, where such offerings are seen as a differentiation strategy to give a provider a clear competitive advantage over alternate offerings (particularly product-only ones)
- An increasing focus and reliance on networks and partners to help achieve the goals and objectives of a PSS – the implication being that PSS providers may not always have the necessary capabilities in-house to deliver such a system, and that partnering and/or outsourcing may be required to deliver such an offering.

9.1.2 Forms of PSS

Moving beyond definitions is the notion of the features and make-up of PSSs. Baines et al (2007) discuss how many have considered products as being separate from services, but that the servitization of products (and a "producization" of services) is changing the identity of product as one that is made up of materials to one where the physical material component is "inseparable from the service system". The same authors also identify three different types of Product-Service Systems:

- Product-orientated PSS where products are sold more-or-less in the same way as before, but with services sold concurrently as part of the same sales act.
- Use-orientated PSS where the availability of a product or system to be used by the customer is paramount. Extracting benefits from the product-in-use is the key aim.
- Result-orientated PSS where what is sold is really a capability or result instead of a product.

Johnstone & Dainty [149] have a slightly different view. They view the spectrum as ranging from "enhanced service offerings to fully integrated solutions". Gebauer et al. [150] approach the various types of PSS from an environment-strategy fit perspective. This is not to mention the other forms of differentiating the services space as discussed in Section 8.6. The divergence in thought and perception, however, reveals that there are many ways to approach PSSs.

Mont [130] looks at the PSS issue from another perspective, looking at what she considers the main aspects of a PSS. She argues that these key aspects centre on:

- Products, services or combinations of them
- Services offered at the point of sale, including financial services and customer training in product usage

- Product use concepts such as use or result-orientation
- Maintenance services for extending product life, and
- Revalorisation services for closing material loops by taking back products, reusing and recycling materials.

9.2 The prelude to Integrated Solutions

Running in parallel to the concept of Product-Service System is *Integrated Solutions*. Whilst both concepts are often talked about as the same thing (or as sitting on the spectrum of PSS), there are differences, particularly in the derivation of the respective concepts and their focus.

9.2.1 Complex Product Systems

Much of the Integrated Solutions literature emerges from the Complex Product Systems (CoPS) concept. CoPS tend to be expressed as “high technology and high-value capital goods [151],” such as weapon systems, high-speed trains and air traffic control systems [152, 153]. Hobday [154] points to CoPS as “high-technology, business-to-business capital goods used to produce goods and services for consumers and producers”. He continues that they are generally individual or low-production-run systems made up of many interconnected parts. These systems are generally customised to customer needs.

9.2.2 Solutions selling

However, Davies et al. [155] pinpoint this evolution back even further to moves in the 1960s when firms began to devise strategies that focused on *systems selling* – “the provision of products and services as integrated systems that provide solutions to customer’s operational needs”. Mattson [156] claimed such sellers combined “components into an integrated system that provided a solution to customer’s business problems”. Davies et al. [151] described this approach as firms taking “over responsibility for systems previously used by customer organisations as part of their total operational activities, such as inventory control, production control systems, machine tools, IT and telecom networks”. Levitt [157] described the approach this way: “the customer does not just buy a system, but the ‘expectations of benefits’ a system provides for a customer over time, such as an operating chemical plant or telecommunications system”.

Firms who engaged in *systems selling* tended to come at the strategy from two different approaches – one was a vertically-integrated firm that produced all the components for the system. The second was a systems integrator stance, whereby the firm would coordinate the “integration of components supplied by external firms” [151]. Cova et al. [140] contend that this notion of *systems selling* has now moved beyond solving operational problems of their customers, to a strategic approach of “solutions selling” – helping customers achieve their customer’s strategic objectives through solutions, but also providing advice and other consulting-style services.

9.3 Integrated Solutions

The notion of Integrated Solutions has emerged more specifically from the business strategy and business solutions fields, rather than the study of manufacturer transformation. Whilst industrial services have often been ascribed to those which are offered by the systems manufacturer [158], this is not always the case. There is an argument that suggests that independent system integrators, or organisations who integrate products from a broad range of suppliers and then support the whole system, can provide just as valid services for complex systems as system manufacturers [144]. Furthermore, a number of authors have focused on traditional service providers who have moved in almost opposing directions to that of manufacturers in adopting a capability to integrate products, components and systems and deliver those to a customer in an integrated solution. Examples from defence and rail systems have been cited [144, 155, 159].

9.3.1 Identifying Integrated Solutions

Specific definitions of *Integrated Solutions* are surprisingly sparse, as while many authors talk of such solutions, few appear to provide any specifics about what they are intended to mean. This was found by Kapletia & Probert [144] who found "no established definition or interpretation of the term 'integrated solutions'". However, there are some definitions available from the literature that identify Integrated Solutions as:

- "A business model that combine products and services into a seamless offering that addresses a pressing customer need" (Wise & Baumgartner [127])
- "A customised and integrated combination of goods and services for meeting a customer's business needs" (Tuli et al. [160])
- "Providers of Integrated Solutions … identify and solves each customer's business problem by providing services to design, integrate, operate and finance a product or system during its lifecycle" (Davies et al. [159])
- "Innovative combinations of technology, products and services as high-value unified responses to their business customers' needs" (Davies et al. [159])

9.3.2 Key attributes

One of the key attributes of Integrated Solutions is thus their customer centricity of solving *business needs*, as opposed to just technical ones. This point is drawn out by Normann [161] in his book *Reframing Business*:

> "The crucial competence of business companies today is exactly this: the competence to organise value creation. This does not mean that production competence or relationship competence are unimportant, but such competences are now increasingly being 'framed' by the overriding competence of organising value creation far beyond their formal boundaries … The new strategy paradigm … also implies a dramatic shift in how we view customers. The customer is no longer just a receiver, no longer just a source of business, but now actually a co-producer, and co-designer, of value creation".

He continues to state that:

> "a particularly fruitful way of reframing [companies]…is to focus on the customer of the company as the major stakeholder, and to mentally frame oneself as part of the customer's business… A major conceptual implication of doing so is to move away from the traditional industrial view of the customer offering as an output of one's production system to a view in which the customer offering is seen as an input in the customer's value-creation process. This requires the company to understand the customer's business and value-creating process and use that as the basic framework within which one defines one's business … Therefore, true customer orientation means that one has to go beyond the direct relationship between oneself and one's customers to understand the relationship between the customers and the customers' customers – from the 'first' to the 'second-level customer relationship'."

Normann is arguing that a significant aspect of this approach to business is to change the mindset concerning the relationship to the customer. The old paradigm sees a boundary between the customer and the supplier, and an interface through which the supplier provides an output. Once the output has been provided, the supplier is no longer involved. Under this new paradigm, the supplier must strip back the old boundaries, and extend them to their customer's line-of-business. The supplier is now actively working towards accomplishing the goals of their customer. Perhaps paradoxically, a further elaboration by Winter et al. [162] extends this thought to where the purpose of a firm is not to "create value for customers, but to mobilise customers to create their own value from the supplier firm's various offerings".

9.3.3 Implementation of the concept

There is evidence, however, that the implementation of this logic is mixed. Kapletia & Probert [144] found in their research two expressions of Integrated Solutions: Solutions based around products, and solutions truly based around customers or end users. Their study was around military Integrated Solutions, including high-tech platforms. It gives rise to a short comparison between PSS and Integrated Solutions.

Are PSS a subset of IS, or vice-versa? Authors tend to have mixed feelings. Ultimately both concepts are very much the same, except that PSS has emerged from a background of the servitization of manufacturers and generally focuses more on the product that is produced, whereas Integrated Solutions has arisen from the business solutions space, which may or may not involve products. In some instances, it could be seen that Product-Service Systems are a subset of Integrated Solutions – the PSS forming the offering that forms the Integrated Solution. Conversely, as Dainty & Johnstone [149] suggest, Integrated Solutions could be viewed as a subset of PSS where such Solutions exist on one end of a highly-integrated approach, and a loose grouping of product and some service being on the other. Either way, as will be explored shortly, the challenges the present are virtually identical in terms of organisational transformation, strategy, and how a firm organises to provide Solutions.

9.4 Complex Engineering Service Systems

Before moving onto the challenges identified concerning PSS and Integrated Solutions, a more recent term to be devised to encapsulate an integrated, service-driven approach (particularly in the defence and complex systems environment) is *Complex Engineering Service Systems* (CESS). It is a term devised by Ng et al. [62] and represents a more contextualised concept of PSS. They provisionally describe CESS as a notion that “aims to deliver value to the customer through a system of people, processes, assets and technology and the interactions between them rather than the function of the individual components themselves. Such a value is emergent from the CES system and not from a linear chain of operations optimised individually”.

A particular focus is placed on examples of systems in the Defence sector – highly sophisticated and integrated units of equipment that are delivered via service-driven contracting mechanisms, such as outcome-based contracting. Much of the research in the CESS space comes from this style of contracting, and, as a concept, focuses extensively on “the integration of equipment, people and information transformation to achieve excellent outcomes, as opposed to merely high-performance outputs from complex engineered equipment [163].” It’s a focus of discussion in Section 10.4.

9.5 Research status of the Solutions literature

Whilst many of the underpinning concepts date back to at least the 1980s with Vandermerwe & Rada’s work on servitization [114], the broader field of Solutions has grown in academic interest most noticeably since about 2005. A wide variety of literature has been published on the context, spanning from marketing and service-logic considerations, to more philosophical proses on the ‘why’ of Solutions[10], to identifying challenges that are faced in the adoption, implementation and execution of Solutions. These challenges tend to fall along the lines of transitioning to a more service-centric approach and the subsequent need for organisational transformation, organising for servitization, customer acceptance and uptake, and organisational capability considerations. Kapletia & Probert [144] state that the “business solutions landscape remains a difficult area to map”, arguing that it doesn’t conform to existing knowledge and understanding of the nature of products and services.

Typical of much of the research effort in the area, especially for Product-Service Systems which is a much newer field of study, Baines et al. [142] pose five key research questions facing the adoption of the concept:

- How are servitized organisations and PSSs designed?
- How are servitized organisations and PSSs built and delivered?
- How are servitzed organisations and PSSs sustained by the network?
- How can the value-in-use delivered by PSSs be assessed?
- How can ‘traditional’ manufacturing firms make the transition to servitized organisations?

They call for a move away from a “reporting” research approach, where scholars follow developments in the industry and “report” on them, to a more proactive research pose to assist industry in its efforts to change. Kapletia & Probert, however, have an alternate view. Whilst not dismissing the need to research the organisations that deliver Solutions, they contend that the focus must not solely be on the organisations that deliver, but that research into the customer organisations is just as crucial [144]. Much of the research to date focuses on ‘support offerings’ have been primarily examined from the manufacturer/supplier perspective and experiences, with little analysis of the customer experience. Kapletia & Probert argue that from the customer’s perspective, issues include control, ownership, and trust. The issue of “ownerless consumption” (or transversely, ownership without control) has been identified by a number of researchers [99, 115, 142, 149]; so too has the issues of past attitudes by

[10] To consolidate discussions concerning similar concepts, the above notions of Integrated Solutions, PSS & CESS will simply be referred to as Solutions for the rest of this chapter.

manufacturers towards customers, acting opportunistically, generating levels of mistrust within the customer organisation [124].

One of the significant areas of discussion in the literature is that of organising for Solutions, as well as organisational transformation of firms engaging in providing Solutions. The two matters overlap but are distinguishable. Organising for Solutions pertains to how the Solution provider organises itself to deliver the Solution. Organisational transformation, on the other hand, pertains to change management efforts in the Solution provider. This is particularly in the case of a manufacturer who is driving internal reform to become a more Solutions and service-orientated firm.

9.6 Organising for Solutions

Various authors have put forward various archetypes of organisations engaged in Solutions. Baines et al. [122] distinguish three major types of operations: the product-focused operations, product-centric servitized operations, and services-focused operations. Aspects of their framework, summarised in

Table 7, characterises the differences in organisation.

Table 7: Framework of product/service operations [122]

	Types of Operations		
Unit of Analysis	**Product-Focused Operations**	**Product-centric servitized operations**	**Services-focused operations**
Type of company being considered	Larger and somewhat conventional volume production	Product sold with platform of bespoke services	Larger and somewhat conventional services
Principal delivery system	Product focused delivery system	Integrated product and service delivery system	Services focused delivery system
Nature of the delivery system	Tends towards physical transformation of materials into tangible goods	Tends towards physical transformation of materials into tangible assets, sold along with services, to deliver functional capability to the customer	Tends towards creating experiential transformation through facilitation and mediation
Typical scope and capabilities of the delivery system	Design, development, procurement, production, test, and distribution	Design, development, production, test, monitoring, maintenance, repair, refurbishment, upgrading and disposal	Design, co-development, delivery, facilitation and evaluation
Business model: how the company tends to do business	Tends towards transactional based: focusing on producing and selling material artefacts	Tends to be based on a blend of transitional and relationship: focusing on providing an integrated product and service offering that delivers value in use	Tend towards relationship based: focusing on delivery of services
Value proposition: what the customer tends to value	Tends to focus on the ownership of an artefact	Tends to focus on product availability, performance, along with risk and reward sharing	Tends to focus on the delivery of a functional result
Order winning criteria for the customer	Features of product; Purchase cost of product; Specification and Quality conformance; delivery of product	Features of product and service; Total cost of ownership; Availability of product and capacity to deliver services	Features of services; Cost of services; quality conformance of services; delivery of services
Typical value metrics for the internal delivery systems	Cost of production; Product conformance; Delivery performance	Product life-cycle costs; Product conformance and service delivery; System responsiveness	Cost of service delivery; Conformance to customer requirements; Availability and service delivery performance
Planning and control	Tend to focus on replenishment systems, sometimes large and complex, that minimise stock holding costs	Tend to focus on the optimisation of product availability	Tend to rely on project management techniques and individuals themselves to provide responsive service to customer
New product/Service introduction	Tend to use centralised capabilities to fully design and test new products, prior to their entry into production, in order to minimise in-market "disturbances"	Tend to use centralised capabilities for product design, taking particular account of maintenance and repair that complement services co-created with customer	Tend to be co-created, tested and refined, with customer in the field
Customer relations	Tend to have limited interaction with customers choosing, instead, to invest energies internally to improve efficiencies	Tend to have strong interaction with customer through relationships based on product availability and performance	Tend to invest heavily in developing and maintain relationships with customers.

The framework covers a lot of ground, both in terms of the characteristics of the operations, as well as the internal organising effort. The product-focused operation is typical of a firm who has a product-centric dominant worldview; the services-focused firm from a strong service mindset. Of interest is the product-centric servitized operations where traditional product orientated operations are merged with traditional service-oriented ones, especially the internal organisation of the firm. For example, the typical factors that define success within the firm illustrate the complex interaction between the quantitative and readily measurable factors such as cost and product conformance, and the more subjective measures for service operations. The Table reinforces much of what has already been discussed, but succinctly conveys the broad tendencies between the different types of operations.

There are other organisational forms, too. Allmendinger and Lombreglia [164] put forward the notion of the “embedded innovator” – a firm who provides product-centric Integrated Solutions that pre-empts and deals with problems by feeding data back into R&D and fixing them before they became significant problems. Such an approach is more common with IT-based systems where changes can be more readily made. The authors also identify the “solutionist innovator”. This type of provider attempts to offer complete or near-to-complete lifecycle offerings for a single product line. They state an example of MRI scanner equipment, where the manufacturer takes on all lifecycle activities from design, build, customer training and maintenance. They also discuss, however, the various levels of depth of a Solution – in this instance, lifecycle involvement in the operational provision of the MRI system – going further into activities beyond the usual scope of the manufacturer, including ‘scan the patient’ and ‘interpreting the scan’.

In terms of organising for Solutions , Davies et al. [159] put forward a three-part organisational model for delivering Solutions (as illustrated in Figure 14): Back End units, Front End units, and the Strategic Centre. The Back End units are business units that provide the various components – whether product or service – for integration by the Front End units who are responsible for the integration of the Solution and be the customer-facing unit that delivers the Solution. Davies, and other authors such as Galbraith [129], use the term “Solutions Integrator” to describe these front end units. In a manufacturing application, it would be clear that a back-end unit is where products are produced, as well as certain service-only capabilities are cultivated. The front end is where the necessary back-end ‘outputs’ are brought together, along with any externally sourced components. The Strategic Centre is much like the brain is to the human body, providing the necessary resources, strategy and direction to direct the entire enterprise. Miller et al. [165] echo this approach, stating that firms need a strong front-end to cater to clients, responsive back-end units to create and leverage capabilities, and a strong centre to reconcile client and capability requirements.

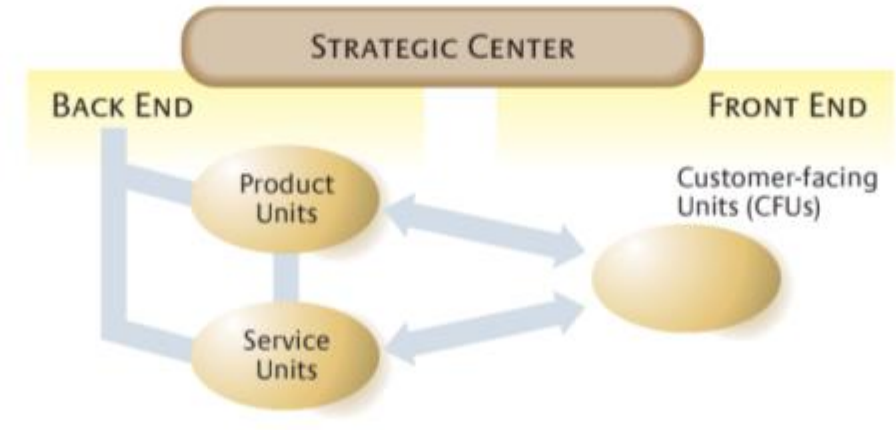

Figure 14: A generalised Solution-delivery architecture [129]

Galbraith [129] gives a series of examples around this point, such as Proctor & Gamble, Nokia, and IBM, with the latter of particular interest. He details how IBM in the 1990s decided to move away from being a product-focused organisation after a period of losses, and towards a Solutions and service-driven approach. IBM established a solutions-orientated business, bringing together whatever software, hardware, and other services required to solve customer problems. Most astoundingly, if the best solution called for the use of a competitor's piece of equipment, for example, this business unit would use it over the IBM product. The Solutions business was not a mere overhaul of the business development function to sell IBM products and services, but was truly concentrated on solving customer's problems and meeting their needs. The subsequent change in fortunes of the company has been attributed to this new approach.

One of the criticisms of the Product-Service Systems approach – although the Integrated Solutions stream of literature does appreciate it more – is too much of a focus on the offer and the customer interaction, and not enough on the organisation that actually must deliver the Solution. Pawar et al. [166] asserts that to create value for the customer, there must be a simultaneous design of product, service and organisation – the overall Solution must consider not just what is delivered (the products and services), but also who and how (organisation). Thus, a growing emphasis on the organisation that provides integration and delivery of the Product-Service System is growing theme. To pose a concept to address this gap, Pawar et al. propose a PSO triangle model – product, service and organisation – as a framework to address this missing knowledge (shown in Figure 15). It is also highly connected to the lifecycle model they propose (discussed shortly).

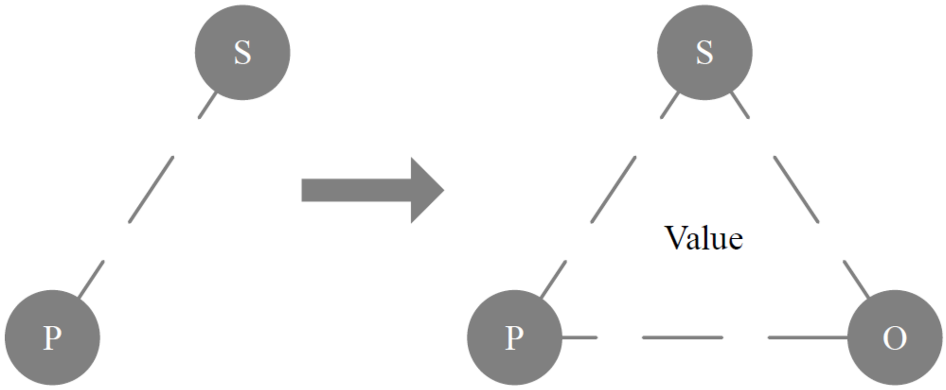

Figure 15: Not just product-service systems, but also a product-service system organisation [166]

9.7 Organisational capabilities required for Solutions

A more specific focus that emerges from the notion of organising for Solutions is that of the organisational capabilities required to actually engage in the Integrated Solutions space. There are calls from a number of authors stating that more research needs to be undertaken to look at the connection between offering Solutions and organisational capabilities [140, 144, 149] (Kapletia & Probert; Johnstone & Dainty; Cova & Salle 2007). This is a point expanded by Cova & Salle [140], who point out the challenge of developing new capabilities in firms who are moving towards the Integrated Solutions approach. Despite a small quantity of contributions on this topic, the existing thought contributions are still notable.

9.7.1 The four prerequisite capabilities model

Brady et al. [136] assert that both service and product-based firms need to develop four prerequisite capabilities in the shift to becoming Integrated Solution providers, including:

- **Systems Integration capabilities:** the ability to bring various systems together and make them work with a higher-order function. This is not just a "sum of the parts" exercise, but bringing many components together to work as one. Whilst generally referring to technical systems or products, this can also mean other soft-systems as well.
- **Operational service capabilities:** The ability to provide a portfolio of services which can be worked with a product to deliver a Solution.
- **Business consulting capabilities:** The ability to work with the customer to improve their own processes and activities, and to understand how to best position a Solution to achieve the greatest benefits for the customer.
- **Financing capabilities:** Oftentimes an Integrated Solution may have some sort of financing element to it, such as a subscription fee approach (i.e., fixed price per year), irrespective of the

initial capital cost. In such instances, the Solutions Integrator firm must possess some way of managing the risks and ensuring that the business model employed for the Solution is a profitable one.

9.7.2 Perish the thought

These four areas raise an interesting point – the perishability of services. In the previous discussion, several authors discuss Back End business units that provide services; yet, those services can only be provided "live" to the Solution. For example, an aircraft maintenance firm, looking to partner with an aircraft manufacturer, cannot merely store maintenance services in the 'back-end'. However, a firm could more readily leverage an existing capability, such as the necessary tooling, supply chains, training programs, licensing and certification, etcetera, to establish a new maintenance operation as part of an Integrated Solution. Hence, this capabilities approach can be a more powerful way of examining firms and their Solutions readiness.

9.7.3 Other views

Other authors have other perspectives on capabilities. Davies & Brady [151] postulate a framework of organisational capabilities in complex product systems, as illustrated in Figure 16. They argue that firms must possess Strategic, Functional, and Project-orientated capabilities. Strategic capabilities refer to a firm's ability to "move into growing markets more quickly, and out of declining ones more rapidly and efficiently, than its competitors". Functional capabilities pertain to the specialist skill and knowledge-sets that are essential in delivering solutions, including design and development, testing, production, supply-chain management, finance, and product-specific management. Project capabilities are seen as those that coordinate the Functional capabilities to achieve the intent of the Strategic Capabilities. This includes the activity of bidding to solve a customer problem, and the execution of the project, including requirements gathering, defining service levels, and managing project risk.

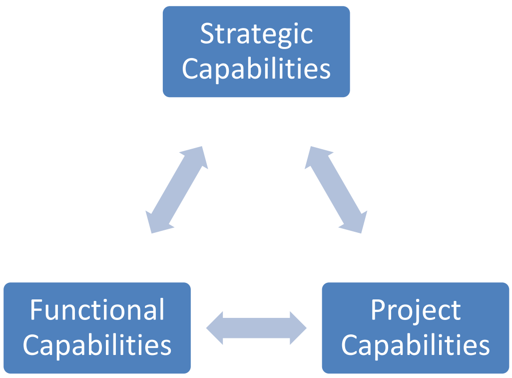

Figure 16: Organisational capabilities for complex product systems [151]

9.8 Organisational transformation

Not all firms who are seeking to engage in delivering Integrated Solutions are necessary well-structured to do so. Brax [124] suggests this includes traditional manufacturers, saying that “becoming a provider of industrial services is not just a matter of the offering; the whole organisation needs to re-focus its attention.”

Insights on such transformation efforts range from straightforward models to more comprehensive approaches. Davies et al. [159], for instance, pose a three-phase capability model for “building repeatable solutions”:

- **Phase 1: Growing the front end.** This involves exploring new ways of providing and delivering solutions, as well as learning from other solutions and projects (both the successes as well as the failures). This covers the customer interface and seeking new opportunities to integrate and deliver Solutions.
- **Phase 2: Building the back end.** This is achieved through developing a suite of standardised “solutions-ready” components that can be more readily integrated with other components, as well as developing partnerships with other product and/or service providers to fill gaps that they identify.
- **Phase 3: Refocus.** This is where the strengthened front and back ends are re-examined in light of a corporate capability suite in the field of Solutions. In particular, creating and refining corporate capabilities that “support large-scale and repeatable solutions delivery”. It is also in this phase that exiting peripheral businesses is encouraged as efforts are focused on providing integrated solutions.

Gebauer et al. [167] echo these sentiments, suggesting that developing an organisation capable of successful Solution delivery must undertake the following:

- Establish a market-aligned and clearly defined process for service development
- Identify the value proposition for the customer, and focus service offers to that end
- Initiate a clear relationship marketing strategy
- Define a clear service strategy, focusing the organisation towards a service-driven approach
- Establish a separate service organisation
- Create a service culture to permeate the organisation.

As useful as these contributions are, it could be seen to be too simple according to other research. For example, Brax [124] argues against incremental approaches to change in manufacturing firms, arguing that such approaches do not “change the system structures that have evolved to support the manufacturing business”. Deep cultural and structural roots can also mean the journey to transformation is not a straight-forward one. Johnstone & Dainty [115], in a study of a large aircraft engine manufacturer offering integrated services, document some more specific issues. These include:

- A disconnect between a product-service strategy, and a dominant product-centric mindset and culture within the organisation
- The disconnect between the parts of the business that interacted daily with the customer, and the parts of the business that supported this more front-line operation, and;
- The implications that a product-centric organisational strategy had on processes and operations of the business, and how this actually impaired the company from tactically focusing on customer needs.

9.9 Lifecycle of Solutions

Several authors propose lifecycle frameworks for Product-Service Systems and Integrated Solutions. These models are helpful in explaining the various phases such concepts encounter and can be a useful tool for both providers and customers to plan for undertaking such endeavours, especially considering the customer-centric nature of such projects (Brady et al. [136]). They can also be used for company management frameworks, used to control the processes used by a firm to deliver a project or solution.

9.9.1 Davies & Hobday model

Davies & Hobday [136] propose the framework in Figure 17. A customer's need first surfaces to the potential provider's attention through a strategic engagement effort. This includes "high-level, pre-bid negotiations with the customer to discuss business problems, often before an invitation to tender has been issued". This helps the firm understand the customer's strategic priorities, goals and objectives, and provides useful intelligence and insight for bidding activities, which is the next phase.

The Value Proposition phase is where the firm considers the best way to respond to the customer's business problem and pose a Solution. This may also involve creating strategic partnerships with other providers to deliver certain aspects of the proposed Solution, such as components, systems and services. In this bid activity, the firm expresses not only its offer but also its value proposition – why their proposed Solution delivers benefits to the customer, and laying out what those benefits actually are.

If a bid is accepted, the firm engages in the Systems Integration phase where actual project execution activities occur. This includes product development efforts (if required), sourcing sub-systems to assemble into the Solution system, and preparing service delivery operations. The final phase is the actual Operational Services phase where the intended benefits of the Solution are intended to be experienced by the customer. It involves the actual ongoing delivery of the Solution and the realisation of the value-proposition of the firm.

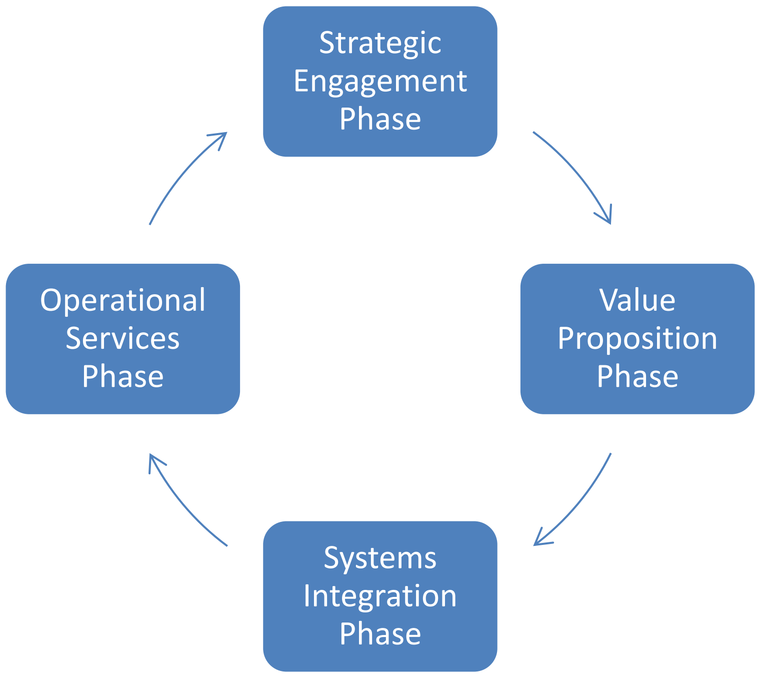

Figure 17: The Integrated Solutions lifecycle according to Davies & Hobday [136]

9.9.2 Pawar model

Based on a similar notion, Pawar [166] posits the framework in Figure 18 as an alternate lifecycle for Integrated Solutions. It is not a fully-fledged model per se, but illustrates the key stages in the process of establishing a Solution, especially focusing on the tripartite product-service-organisation development regime discussed previously.

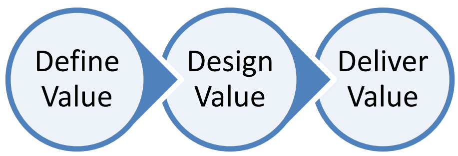

Figure 18: The Integrated Solutions lifecycle according to Pawar [166]

In the Define value phase, apart from defining the value proposition to the customer, on the organisational front, the front-end firm must begin to estimate the cost and assess the risk involved over the life of the Solution. At the Design Value phase, the integrated system that delivers the value proposition is developed, but so too is the organisation that must deliver it. These include preparing the capabilities necessary “complement the core competencies of the firm”. Finally, in the Deliver value phase, the Solution is put into operation, often in conjunction with partners. It’s also where the provider must constantly be assessing its performance and managing the quality and consistency of the Solution’s delivery, particularly looking at refining, improving and streamlining internal practises that give that firm the capability to deliver.

9.9.3 Alderman et al. model

Alderman et al. [168] put forward their own framework based on work by Wotherspoon [169]. They conceptualise the engineering design process, in the context of engineering-based Integrated Solutions, has having three distinct phases:

- Seeding
- Negotiation
- Accomplishment.

The Seeding phase is very much a creative space where ideas concerning addressing a customer issue are developed, evaluated and either accepted or rejected. It can be quite a fluid and extended phase. It includes activities such as tendering, contract negotiation, and feasibility assessments. The Negotiation phase is where these high-level needs become detailed requirements, and where a Solution concept is worked-up to meet these demands. The Accomplishment phase describes the actual implementation of the Solution and the realisation of its benefits.

9.9.4 Tuli et al. model

Tuli et al. [160], contending that because much of the Solutions and product-service literature is focused on the provider rather than the customer, propose a four-step framework that customers use when perceiving a Solution:

- Customer requirements definition
- Customisation and integration of goods and/or services
- Their deployment, and
- Post-deployment customer support.

9.9.5 Challenges forming a Solutions lifecycle

It becomes clear that there is no "one-size-fits-all" approach in defining a lifecycle approach for Solutions.

Product-centric lifecycles, such as the systems engineering lifecycle, are perhaps easier to identify since the core perspective is that of the product. Such models conceptualise the 'journey' that a product or system will find themselves passing through (see Figure 19). This includes the communities of people who engage with that product which tends to change depending on the phase the product is passing through. For example, the manufacturing phase is primarily the domain of manufacturing divisions or organisations, whereas the operational phase is primarily the domain of operators and product support teams.

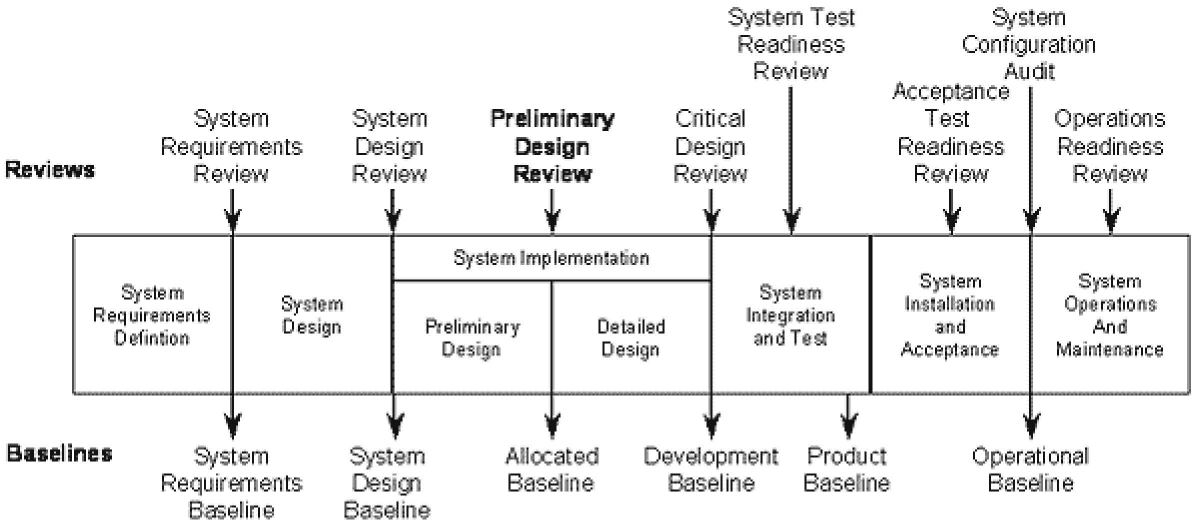

Figure 19: Systems Engineering lifecycle [170]

Lifecycles of Integrated Solutions, however, must consider several other factors and perspectives – primarily organisational rather than product. This includes the integration of the customer, the Solution integrator, the network of partners and suppliers, as well as non-social factors such as complex technical systems. Whilst a number of concepts have been put forward by various authors, there is still room to increase the level of knowledge of the Solutions lifecycle in several areas, including further detailing the operational phase of a Solution. Solutions can last for decades, whereas the establishment of them may only take years or even months. Further, breaking out the interaction between the product, the service elements, the organisation, and other elements that make up the Solution would be one way of honing on a more cogent lifecycle concept.

9.10 So what?

So where does this review leave this report? So far, this review of conceptual building blocks has examined the difference between product and service-centric thinking, the impulse for manufacturers to become service providers, and some of the business models, such as Solutions, which this impulse can be pursued through. This chapter, in particular, has covered some of the definitions, challenges and conceptual frameworks that assist executives and managers in organising and operating Solutions.

However, whilst there has been a concerted effort in academic circles to report on developments in offering Solutions, there remains gaps, or opportunities for improvement, in frameworks and ideas to more cogently understand and manage Solutions. In terms of this overall study, much of the reviewed material should be thought of as a conceptual primer – initiating ideas that help put language and organised schemes around a business world that is quite difficult to classify. But they're also the starting point – the prior knowledge and ideas about Integrated Solutions – that trigger much of this study's own search for insights for a management methodology for Complex Integrated Solutions. These include:

- How to mentally conceive the Solutions concept
- The nature of Solutions, in terms of how an offering might be structured for a customer, and the various ways or stages Solutions exist
- The types of organising concepts and capabilities necessary to compose and deliver Solutions

- The real-life challenges that Solution providers may face when seeking to adopt a Solutions-approach.

Of course, this study doesn't seek to understand Solutions just generally; rather, it seeks to understand Solutions in an aerospace fleet management context, although the lessons from this study might be worthy of being passed back into a more generalised body-of-knowledge. Thus, it's important to examine in a little more detail the emerging fields of sustainment, logistics and asset management to better appreciate the nuances of what is quite a technical endeavour. This is the pursuit of the next chapter.

CHAPTER 10

A Critical Enabler

The Emerging Sustainment, Logistics & Asset Management Fields

10.0 The science of Sustainment

Whereas previous chapters have focused on general service, servitization, and Integrated Solutions concepts, this chapter moves these concepts closer to the aerospace sustainment context, by examining the foundational technical concepts such as logistics and supportability engineering. Whilst the uptake of performance-based logistics business models might be a more recent development, the discipline behind logistics support and sustainment has its origins back to World War Two.

This is an important chapter for other reasons, too. It explains much of the traditional, or conventional, approach to supporting and sustaining complex systems such as aircraft. It looks at the underlying system-of-thought that drives much of how conventional sustainment programs have been structured, and the management methodology and logic that are used to operate them. In addition, it's a particularly useful reference piece when examining the question of 'what is engineering' in Chapter 26.

The purpose of this chapter is four-fold:

- Review the fundamental concepts that underpin the operations of the Integrated Solution case studies that are presented in Part III, namely logistics and sustainment engineering
- Critically review some (not all) aspects of these concepts, particularly those that have dominated existing thinking, and that are steeped in product-centric thought
- Begin to examine the cross-over between sustainment Solutions/operations and the role of professional engineering in such contexts
- Take a closer look at how sustainment and logistics concepts are enacted and deployed as a business model, rather than as a discipline.

10.1 History of logistics and supportability engineering

10.1.1 Supportability engineering in the lifecycle

Both Jones [53] and Blanchard [82] are recognised as thought leaders in the realm of logistics engineering, and both base their description of logistics from the perspective of Systems Engineering.

Jones[11], in the introduction to his text on Supportability Engineering, details the history of the logistics concept and its importance for operating today's technology, particularly within the context of the United States. Prior to World War 2, the military utilised equipment that was very straight-forward in operating (consider that aircraft were made from wood, cloth and had very limited, but simplistic, instruments, and where 'weapons delivery' was simply by throwing munitions 'over the side'). However, during World War 2, military equipment became increasingly sophisticated with a significant growth in the technical complexity of the systems.

When developing equipment for the war effort, designers focused all their development efforts on the performance of the equipment, discarding any detailed concerns about supporting the systems, or the cost of development. This led to issues in the field with supporting the equipment, but with the desperation of the war effort, coupled with the economics at the time, these issues could be 'solved' by simply manufacturing a significant volume of equipment.

However, once the war had finished, there was a greater awareness within the military establishment about the importance of supporting systems, and to consider this whilst developing them. To that end, several centres of excellence in specific areas of support (many which ultimately became the nine components of Integrated Logistics Support (ILS)) were established. They included:

- Operation and maintenance planning
- Manpower and personnel
- Supply support
- Technical documentation
- Training
- Support and test equipment
- Facilities
- Packaging, handling, storage, and transportability.

10.1.2 Integrated Logistics Support

These different centres were brought together in 1965. This culminated in the establishment of the ILS concept, under a charter claiming ILS was:

> "The disciplined and unified management of logistics technical disciplines to (1) participate in the development or selection of the design of the product and (2) plan and develop support for the product."

Predicated on this charter, four key-goals of ILS were established. These were:

[11] Unless specified, much of the next few sections are taken from this seminal text.

- Achieve the lowest cost of ownership
- Influence design decisions for support
- Identify cost drivers
- Identify and develop support resources.

This lead to Integrated Logistics Support as being defined in DOD Guide 4100.35G as:

> "A composite of all support considerations necessary to assure the effective and economical support of a system or equipment at all levels of maintenance for its programmed lifecycle. It is an integral part of all other aspects of system acquisition and operation."

Following the unification of the ILS centres-of-excellence that the concept of ILS became more significantly engrained in the development of new military systems. However, the emphasis was still on planning the logistics requirements for supporting the product once it had entered service and was done as a post-design activity, meaning that the ILS community could not strongly influence the supportability aspects of the system whilst it was been build, and before those characteristics were locked in for good. This wasn't helped when the dominant view at the time being that system design was for contractors, and logistics was only for the military organisations which operated the system; the only part the military organisation played in the design was setting the performance specification.

To remedy this, the Defense Department stipulated in their contracts the need to perform ILS analysis as part of the development process, but alas, this analysis was generally completed after the system design was complete, again, influencing the design very little. During this whole period, systems only became increasingly complex.

10.1.3 Enter Logistics Support Analysis

In 1984, the Defense Department again sought to remedy the situation, this time by adopting the concept of Logistics Support Analysis (LSA), itself developed from industry best practise. It involved a methodology for incorporating ILS principles up-front into the design process for the system and would involve analysing the support requirements for the system before, whilst, and after the system was designed. However, the same issue of making the support analysis a 'bolt-on' to the established system design continued to occur.

As with many definitions and conceptual frameworks, the concept of ILS had also changed over several decades. In 1994, a new definition was released by what is now the Defense Acquisition University, and states that ILS is:

> "The disciplined, unified and iterative approach to the management and technical activities necessary to (1) integrate support considerations into system and equipment design, (2) develop support requirements that are related consistently to readiness objectives, to design, and to each other, (3) acquire the required support, and (4) provide the required support during the operational phase at minimal cost."

10.1.4 Acquisition Logistics

In yet a further attempt, the US Defense Department released another military standard, *MIL-HDBK-502 Acquisition Logistics.* The standard provides a clearer methodology for the application of ILS principles as new systems are designed, built and fielded, and is still used today in US DoD programs. It's defined as:

> "… a multi-functional technical management discipline associated with the design, development, test, production, fielding, sustainment, and improvement modifications of cost effective systems that achieve the user's peacetime and wartime readiness requirements. The principal objectives of acquisition logistics are to ensure that support considerations are an integral part of the system's design requirements, that the system can be cost effectively supported through its life-cycle, and that the infrastructure elements necessary to the initial fielding and operational support of the system are identified and developed and acquired [171]."

It divides logistic support analysis activities across two key areas – *functional logistics* where ILS teams participate in the development of the design, and *physical logistics*, where the ILS team identifies, develops and delivers the resource package necessary to support the product in its operational environment (the post-design logistics profile planning).

10.1.5 The rise of supportability engineering

The next evolution of the analysis, planning, incorporation and delivery of the cost-effective support of fielded systems is encapsulated in an emerging field called *supportability engineering* – one of the so-called "RAMS" concepts (Reliability, Availability, Maintainability, and Supportability, although there is some debate as whether this should be sustainability or even safety [172]) that's used when discussing logistics. It often used interchangeable with Logistics Engineering or Logistics Support.

10.2 A closer look at logistics & supportability engineering

The term *logistics* is derived from the French word *logistique* ('the art of calculating'), itself taken from the Greek *logistikē* (also the art of calculating), which ultimately was taken from another Greek word *logos* for 'reason/rationality'. Whilst the use of the term *logistics* in today's society often relates to transport and cargo, it is deeply rooted in the notion of planning and coordinating. In the military context, the term has a more targeted meaning, referring to the discipline of ensuring that the right equipment, resources, supplies and other materiel are delivered where they are needed, when they are needed. Thus, the study of logistics and supportability engineering cover a lot of ground, including maintenance, spares, training, reliability, failure and availability analysis, and testing. It also interfaces significantly with systems engineering.

10.2.1 Logistics or supportability engineering?

Distinguishing between logistics versus supportability engineering is difficult, not just because they're very similar concepts, but also because of where they're applied. A lot of supportability engineering is now becoming a 'voice for the operator' in the design and development stages of a new system, but it's also a discipline that applies in the in-service environment. Logistics engineering, on the other hand, has traditionally been very operationally and capability-generation focused but has over the years sought to extend back into the design and development realm to influence the development of new systems (hence the rise of supportability engineering).

So, what precisely is now meant by logistics and logistics engineering?

10.2.2 Logistics engineering & logistical support elements

Blanchard declines to offer his own high-level definition of logistics, but rather provides his view from a total lifecycle perspective, explaining that *logistics engineering* is:

> "The initial definition of system support requirements; the development of criteria as an input to the design of not only those mission-related elements of the system but the support infrastructure; the ongoing evaluation of alternative design configurations through trade-off studies, design optimisation, and formal design review; the determination of the resource requirements for support based on a given design configuration, and; the ongoing assessment of the overall support infrastructure with the objective of continuous improvement through iterative processes of measurement, evaluation and recommendations for enhancement [82]."

Down to the business-end of logistical support is the US DoD's framework for managing product support [41]. These are twelve elements that are based on the traditional nine elements of Integrated Logistics Support and are now referred to as the Integrated Product Support (IPS) Elements. These are:

- **Product Support Management:** Overall product support coordination and management
- **Design Interface:** Involvement of a supportability voice and presence in the design and development realm to influence the forthcoming system (or update) to be highly 'supportable.'
- **Sustaining Engineering:** Much of the scope of the Embedded Engineering Function for this study, but also includes other engineering efforts to maintain the system's baseline, find improvement/enhancement opportunities. This might be done by other engineering outfits, such as the system design organisation.
- **Supply Support:** Planning, resourcing, and coordination of efforts to ensure parts, consumables and other elements needed for the ongoing operation of the system.
- **Maintenance Planning and Management:** Planning, resourcing and actioning the maintenance requirements of the system.
- **Packaging, Handling, Storage and Transportation (PHS&T):** Particularly for deployment, but also when at a fixed operating location, ensuring an appropriate capability for dispatching and receiving of all essential elements to ensure the operational capability of a system requires careful attention.
- **Technical Data:** Complex systems require significant swathes of technical information and data to be operated safely. This is an important element that must be managed from identification, through to production, through to distribution. This includes approved manuals, system

specification, design and testing blueprints/data, and other defining/supporting documentation.

- **Support Equipment:** Complex systems require support equipment for their use, such as ground-test equipment, ground-handling equipment, specific tooling or power supplies
- **Training and Training Support:** A capability built around a complex system cannot be fully realised until the necessary operating and support crews are fully trained in its operation and sustainment.
- **Manpower and Personnel:** Any complex system needs a complement of trained crews to operate and sustain it – but understanding the exact resourcing requirement is important to operate that capability at the most cost-effective level.
- **Facilities and Infrastructure:** Whilst a complex system might be able to use existing facilities, they must first be qualified as suitable. If not, new facilities may be required.
- **Computer Resources:** Supporting a sophisticated system is a complex endeavour. Thus, computerised support systems are essential to track the enormous swathes of data and system configuration items that require accurate record keeping.

These are not necessarily organisational units or divisions; they are the essential ingredients and areas of activity necessary to ensure the successful upkeep and operation of complex systems such as aircraft, submarines and combat systems.

10.2.3 Support & supportability

Logistics engineering is also the bridging between the operational needs of a customer and the engineering and technology processes used to deliver it. It does this over varying time periods, with logistics a consideration at the design of a system, at the implementation, day-to-day use, and long-term planning surrounding a product. This becomes evident in the field of *supportability*, a term derived from the concept of product-support. Jones defines *support* as:

> "The *physical act* of enabling and sustaining an item to achieve a pre-determined goal or objective";

and thus defines *supportability* as:

> "A *prediction or measure* of the characteristics of an item that facilitate the ability to support and sustain its mission capability within a predefined environment and usage profile."

Blanchard has a slightly different view, claiming supportability "relates to the degree to which the system can be supported both in terms of the inherent characteristics of the prime equipment design and the effectiveness of the overall support capability, that is, the elements of logistics support." MIL-HDBK-502 defines supportability as the "degree to which system design characteristics and planned logistics resources meet system peacetime and wartime requirements" (noting that this standard is focused on military systems).

Whilst views vary about the definition of system supportability, common themes include that it covers:

- Both the notion of inherent reliability of a product from design, as well as the ongoing capability of the organisation that is supporting the product)
- The 'relationship'/interaction between the product and those who are supporting the product

- Ensuring that the product is supportable in the long-term. It's not a 'set and forget' situation; rather, such systems require other essential elements to preserving the longevity of the product which themselves face functional and availability challenges. This includes a pipeline of spare parts, the modifiability of the product, access to data and expertise to solve problems with the system, and ensuring that these elements are still available after system manufacturing has been wound-up.

10.2.4 Supportability engineering

So, what then is "supportability engineering"? Jones reflects on the concept as:

- "A relatively new engineering discipline that has developed with the evolution of technologies that have created significant support challenges
- Is an engineering discipline that works within the systems architecting and systems engineering activities that develop a new system
- An integral part of the system engineering process that is responsible for ensuring that the final design solution contains characteristics and attributes that will allow it to be supported."

He also qualifies these statements, saying that supportability engineering has application for both new-product-development programs, as well as off-the-shelf programs. While off-the-shelf programs mean that the supportability engineer cannot readily change the systems supportability characteristics, they can be astute to understand the supportability profile of that system, informing the customer of the risks and the potential support resources required.

10.2.5 Engineering techniques

There are, too, specific techniques, methodologies, and concepts that help both the supportability/logistics engineer in their responsibilities. Whilst this study doesn't seek to go into much depth on them (there are other experts and resources that deal with these concepts with much more aplomb), it would be remiss not to review them very quickly. These concepts include:

- **Reliability:** Including reliability modelling, analysis, and monitoring
- **Availability:** Related to reliability, but particularly focused on defining, modelling and tracking system availability measures
- **Maintainability:** Efforts to model the resourcing, accessibility, and efficiency of performing maintenance on a system. It's a supportability measure, whilst also being a system attribute that can be redeveloped
- **Supportability:** As discussed in the previous section.
- **Reliability-Centred Maintenance:** a maintenance requirement determination methodology to devise a maintenance program
- **Lifecycle Costing:** efforts and methodologies to identify the drivers of costs, and to model the cost of operating a system. This can be done before a system's fielding (as a projection), as well as a from a dynamic evaluation perspective.
- **Configuration Management:** The discipline of managing critical information in a structured and systematic way to provide engineering teams and clients with a single source of truth on technical matters about a system.

The first four are known throughout the logistics community as "RAMS" and pertain to measurable aspects of the system – as targets to be designed for, as actual inherent design behaviour, and as measures to be monitored throughout the life of the system. The others are key techniques that feed into the RAMS analysis, as well as the key elements of logistics activity.

10.2.6 Measuring supportability

So, how is supportability measured?

Specific measures of supportability are not readily forthcoming, although Blanchard describes many of the Logistics Support Analysis concepts detailed here as part of the portfolio of *supportability analysis* (SA). The concept of supportability might also be considered to be thinking about the future of the product. The Defence standard that drives supportability considerations in US DoD acquisitions describes a series of criteria for supportability, including:

- **Cost:** affordability is key when budgets are limited
- **Equipment readiness:** this is a measure of the effectiveness of the organisation(s) involved in supporting a system. Being able to predict the level of readiness of a system helps the organisation plan for the introduction of the system
- **Manpower & personnel constraints:** similar to the issue of cost, the organisations who will operate such systems will realistically have staff resource constraints that should be considered when developing the system
- **Anticipated service-life:** this will play a big part in the design of the system, as well as the way in which the operating organisation is set-up.
- **Compatibility:** ensuring that the system can be used with existing systems, and in the case of payloads, actually use existing systems
- **Warranty period:** guarantees that the system will remain useful over a defined period
- **Documentation & data:** ensuring that the necessary information to keep the system operational is available and provided
- **Transportability:** ensuring that the system can physically be moved to the location where the system is needed
- **Post-production support:** when production of a system ends, ensuring that there is a support framework in place to ensure continued operation of the system
- **Design flexibility and degree of system openness** moving towards a design philosophy of "open systems" whereby sub-systems can be upgraded or replaced, without causing a major systems integration issue [171].

10.2.7 Out of the vacuum

This study contends that logistics engineering is a discipline – that is, defined by a body of knowledge and can be studied. However, many Defence departments have sought to make it a profession (with associated career tracks), and also a management methodology. Thus, the following section - and indeed, the rest of this study – must be viewed as alternate business activity typologies which use the core science and skills of logistics engineering, but enacted and deployed in different ways. The science might be same, but the organising concept may not.

Whilst this review of logistics and supportability concepts is enlightening, they're staid and theoretical until they're enacted in some way. How this concept with its requisite knowledge and methodologies is enacted must also be looked at to better understand and appreciate it.

10.3 Enacting Sustainment

Noting that Solutions is a program structure to meet a customer's business needs and that logistics/sustainability engineering is the workstyle means that meets those needs, fusing the two together represents a business activity typology of fleet management. It's this typology for which this study is seeking to generate insights for a management methodology.

What, then, are some practical ways in which these two concepts are fused together? This section looks at four specific forms:

- Asset Management
- Service-Led Projects
- Complex Engineering Service Systems
- Airline Maintenance Organisations.

This section follows on from the previous chapter on Integrated Solutions, but with a stronger engineering, sustainment or logistics pedigree. It's also engineering from a service-centric thinking worldview, rather than a product-centric one.

10.3.1 Engineering Asset Management

A field that has grown out of the traditional maintenance engineering discipline is the concept of Engineering Asset Management. One of the first associations to make this move was the Asset Management Council in Australia who defines Asset Management as the "lifecycle management of physical assets to achieve the stated outputs of the enterprise [173]."

The Institute for Asset Management, based in the UK, offers a similar set of definitions. They define it as:

> "the management of (primarily) physical assets (their selection, maintenance, inspection and renewal) plays a key role in determining the operational performance and profitability of industries that operate assets as part of their core business … Asset Management is the art and science of making the right decisions and optimising these processes [174]."

Their official definition continues to explain that "a common objective is to minimise the whole life cost of assets" and that it "represents a cross-disciplinary collaboration to achieve best net, sustained value-for-money in the selection, design/ acquisition, operations, maintenance and renewal/ disposal of physical infrastructure and equipment."

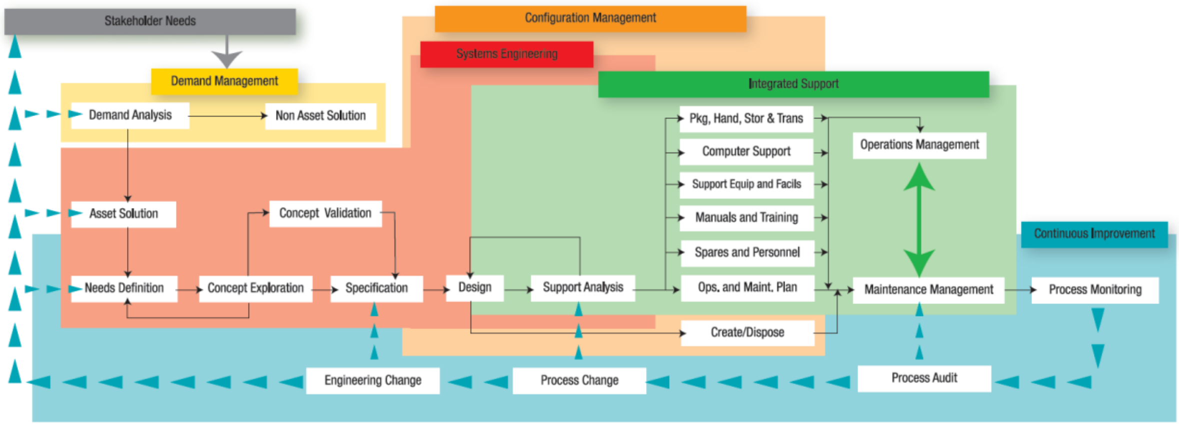

Figure 20: Asset Management Technologies Model [175]

Much of the focus of these Asset Management communities has been on large-scale, fixed plant equipment, such as mining, water, power generation and other utility providers, as well as large mobile assets such as military ground-based systems, warships, and aircraft. However, when reviewing papers and articles from each group, it becomes clear that this second group of assets (i.e., mobile, fleet-based systems) are far less covered than the first group. This could be due to the historical membership base of these associations being in the maintenance engineering sector [176].

The Asset Management material still emphases product-centric thought, although it does also emphasise delivering business outcomes. It also tends to be seen as an organisational discipline within firms, such as the production facility of a petroleum company where the processing facility is but one part of the company's core business. The focus is on system upkeep, rather than repair, whilst reducing costs. These are certainly goals in-line with Integrated Solution offers and management, and thus the Asset Management approach has much to offer to firms who are engaging in delivering Solutions. However, the product-focused approach of Asset Management must be appreciated before adopting the core-reasoning of the AM field.

10.3.2 Service-led projects

Alderman et al. [168] express the notion of Integrated Solutions using the term *service-led projects* to convey instances where an industrial firm is engaged in the design, assembly, delivery and maintenance of complex systems. Whilst framed from a project-management perspective, this approach is also strongly led from a service-centric approach. It is also a term that emerges from the Complex Products and Services (CoPS) literature.

The approach is characterised from several perspectives:

- **Complexity:** Alderman et al. [164] argue that such projects shift the core focus of the firm away from the delivery and support of products or systems (themselves within the strict confines of constructs such as warranty periods), and towards "a new realm of project complexity."
- **Customer Intimacy:** Hobday [154] views it as a contrast, suggesting that it has been assumed that products are developed 'for the marketplace', whereas CoPS are usually "transacted with

the user (and other suppliers) in unique combinations and rarely, if ever, transacted in an arm's length market setting".

- **Benefits-not-Production:** Winter et al. [162] assert the notion that projects and programmes should be seen through the perspective of value-creation processes, rather than a "classical engineering view of temporary production" as part of a growing shift away from "traditional engineering view of projects" towards a "more value-centric view." They characterise this shift as one in which "the primary concern is no longer the capital asset, system or facility, but increasingly the challenge of implementing business strategy, improving organisational effectiveness and managing the realisation of stakeholder benefits."

The concept of service-led projects is held up in stark contrast to traditional project management concepts where the existing key metrics used – namely specification, cost and time – are primarily product-centric [162][Winter et al]. Some authors reinforce this view, such as Ballard & Howell [177] who emphatically assert "projects and programs are temporary production systems." Winter et al. don't disagree with this view – within context – suggesting that projects and programmes can "be seen from many different perspectives, including the image of temporary production systems, but also as value creation processes, change processes and temporary organisations."

10.3.3 Complex Engineering Service Systems

Complex Engineering Service Systems, a concept put forward by Ng et al. [178], are strongly linked to Product-Service Systems, but in this instance, both the product and service elements are extremely high-tech, such as advanced medical equipment, aircraft, and other advanced military systems. It also refers to Solutions where "merely providing a prepaid solution" is seen as inadequate, as the goal of CESS is to focus on end-states. Firms need to consider "the effect or consequence of the asset through its usable life."

10.3.3.1 Beyond technical performance

CESS is also characterised not only by end-states but by a series of other factors. These include how the boundaries between the firm and the customer are blurred, that the core value transformation mechanisms are material/equipment, information, and people and that the processes of these value transformation mechanisms are also blurred. At the core, however, is the focus on end-states, although the authors note that this increases the blurring of responsibilities and accountabilities for the Solution system.

Much of the research in this space has come through a research program [178] at the University of Cambridge known as S4T or "Support Service Solutions: Strategy and Transition." As part of the research program, they have examined various large-scale support programs run by contractors for a customer (generally of a military kind), such as the Tornado ATTAC program. From there they have derived a series of insights about the nature of managing such programs. Arguably, it is the only sector of literature that has more closely looked at the management of large-scale, technologically-involved Solutions, rather than just the highlights of such programs.

10.3.3.2 Affecting state-changes

Ng et al. describe a model (as seen in Figure 21) describing the core ideas of CESS. The major themes include co-creation of value with the customer, state-dependant outcomes, and transformation processes to achieve those outcomes.

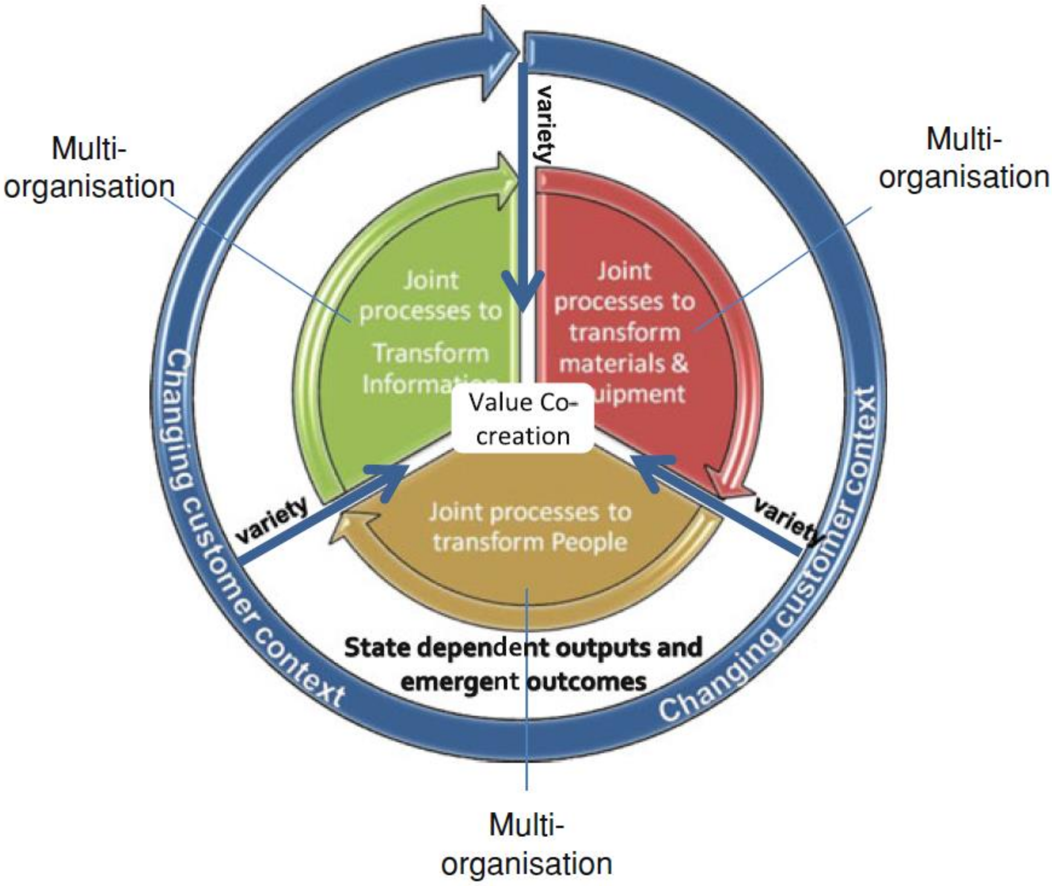

Figure 21: Complex Engineering Service Systems model [62]

The authors construct a hierarchy of outcomes to explain the notion of state-dependant outcomes (Figure 22). As the baseline, such arrangements can deliver certain products and services in an unintegrated fashion (described as “time and materials” in the sense of traditional maintenance practises). Building on this is the idea of availability-based contracting, followed by contracting for a capability. However, the authors also expand to another level – desired end-states. This is the actual effect that the customer is after. It might be obtaining video surveillance of a target, through to the effective disruption of command and control in a hostile force[12]. Nevertheless, the framework illustrates the range of outcomes a CESS could ultimately deliver.

[12] This does, however, raise questions about non-state actors engaging with state actors in a potential conflict.

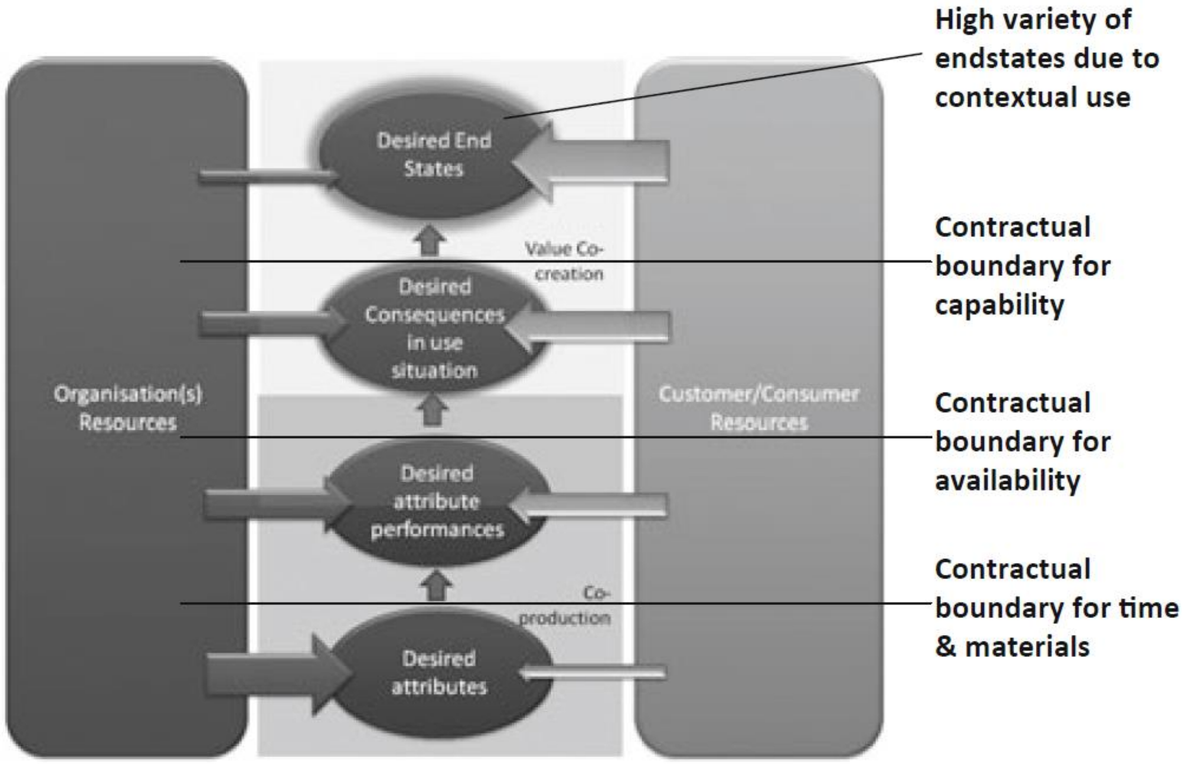

Figure 22: Hierarchy of outcomes in CESS [62]

10.3.3.3 Concept of value

The research also reveals some practical insights concerning CESS in-use. For instance, it illustrates that "value-in-use … is not a static concept. The notion of 'use' is dependant the 'state of the world' and customer's use in different states (i.e., contexts) [62]". They extract the theme that unlike traditional systems engineering, which develops products in a relatively static environment where requirements are relatively fixed, and the design solution is produced independent of the customer, under a CESS approach, working with the customer introduces many new levels of variability and variety. They quote research by Frei [179] that looks at the effect on Solution design when "throwing the customer into the works." Frei identifies five types of variability:

- **Request variability** – different requirements for each customer
- **Arrival variability** – peaks and troughs in the service demand
- **Capability variability** – customers having differing skill levels
- **Effort variability** – some services require customer input/participation and customer will have differing willingness to make effort
- **Subjective preference variability** – different and contradictory views of what constitutes good service.

The authors also discuss what they call "state of the world" effects – contextual and environmental factors that can have an impact on the Solution's goals and objectives. They can include physical conditions, such as the operating environment (such as hot, dusty, cold, icy, humid, etc.). However, it can include many other factors, such as domestic political developments, global political developments, the growth of certain threats, and so forth. When considering these factors, it becomes clear that a Solution delivery firm's processes and business structure need to be flexible enough to provide a Solution – that is, a response that solves a customer's problem in both a real as well as experienced sense. However, in describing how such a dynamic environment can affect the successful delivery of a Solution, the authors warn that "most disturbingly, variety permeation into the system often by-passes the firm's designed processes, disrupting them and creating complexity. This is paradoxically a consequence of the firm's original and implicit assumption of low customer usage variability when designing the system".

10.3.3.4 Systems-versus-service thinking

The non-linearity of CESS is a consistent theme throughout the research. However, much of the systems thinking and models that are traditionally used when solving such customer problems, especially in the engineering space, are driven by linear thinking (Wood & Tasker). Focusing particularly on the people thread of the CESS framework, Wood & Tasker address this issue of the complexity of Solutions by contrasting service and service thinking [65]. They state that:

> "The system engineering thinking style is deeply embedded in the development of complex systems, especially defence systems where it has become a universal language; systems of regulation and governance are built on it. Notwithstanding the development of soft systems and similar approaches, system engineering thinking is perceived to be inextricably rooted in the product paradigm ensuring a cultural rigidity inhibiting development of the method to accommodate design in the social space necessary for the attainment of service excellence. It is therefore important to develop complementary techniques for service design in the social space based on ''service thinking'' and the theory of mind, leading to new perspectives on leadership and the building of expert teams."

They contend that the systems engineering approach, whilst useful for developing advanced and complex systems, is only capable of handling predictable properties, whereas a core characteristic of CESS is emergent properties. Systems engineering has its strength in deterministic outputs, but when social factors such as subjective – nonetheless very real and important – perceptions of service excellence are introduced, another approach is required. This is where both Wood and Tasker, as well as Ng et al. argue that the CESS approach can fit. It combines both the deterministic attributes of advanced technology-based systems, with the emergent outcomes that are experienced, rather than measured. Ng et al. explains how it is this "challenge of contracting, designing, engineering, and delivering end-states that include both deterministic outputs and emergent outcomes sets the agenda for future research in complex engineering service systems."

10.3.4 Engineering in aircraft operator maintenance organisations

Getting to grips with the nature of aircraft maintenance that is attached to a major aircraft operator (such as an airline) presents a surprisingly sparse offering of published insights. Kinnison [63] identifies a gap in centralised knowledge about aircraft maintenance management. Whilst several texts exist on topics such as logistics, general maintenance management, and principles, and specific aircraft maintenance practises, there exists virtually no material that is specifically applicable to aviation, whilst still at the management level, and of sufficient coverage.

Kinnison's text deals with the concept of an aircraft maintenance operation that is part of a larger operator, and so the ideas don't entirely hold up for independent maintenance providers. Also, his ideas were presented before the major advancement in regulations that clearly diffuses the actual activity of maintenance from that of continuing airworthiness management, namely with the concept of Continuing Airworthiness Management Organisations (CAMOs) [180]. This is a more relevant concept to professional engineering and is discussed in the next chapter.

Nonetheless, Kinnison's work does give a useful baseline for understanding such Engineering & Maintenance operations, which will be particularly useful for case study 2 in this report. He identifies five core sections within an airline maintenance operation:

- **Technical Services:** including planning, engineering, training, publications, and information management
- **Aircraft Maintenance:** comprising hangar and line maintenance activities, as well as the Maintenance Control Centre (MCC) – whereby the maintenance needs of each aircraft in the fleet are tracked and planned for in conjunction with the Flight Operations Group of an airline operation
- **Shop Maintenance:** consists of the major shops that perform maintenance on components and sections removed from the aircraft, and can be said to include engine, avionics, mechanical, and specialist structures
- **Materiel:** is involved with the purchasing, stores, inventory control and receiving of goods associated with the maintenance program. Spare parts are a major activity for this section
- **Maintenance Program Evaluation:** comprises Quality Assurance, Quality Control, Reliability and Safety functions within the maintenance organisation.

Regardless of the author, the engineering function (insofar as of a professional engineering provider) tends to be found within the Technical Services stream of the maintenance group. They are responsible for the processing of airworthiness requirements that emerge during the in-service phase of the aircraft, assist the airline with technical advice (such as the introduction of new aircraft or cabin interiors), solve technical problems that are discovered with the aircraft (in conjunction with the manufacturer), and devise authorised repair schemes for the aircraft that are not covered in the maintenance publications.

10.4 Does logistics or supportability engineering yield a useful management methodology?

Returning to this study's core question – namely about finding a management methodology – how does this logistics and supportability engineering field help?

As previously discussed, this field represents a discipline that can be studied and has been used by Defence Departments as a framework for helping generate operational capability through ensuring system availability. It presents a useful integrating framework for complex situations, such as Defence Departments trying to wrangle a myriad of factors. However, does it make a suitable approach to operate and manage a contract (particularly from the contractor's perspective)?

This study suggests the existing suite of logistics and supportability engineering knowledge doesn't account for the nuances and business realities of offering Complex Integrated Solutions. In addition, while the science of reliability analysis and the discipline of configuration management appear sound, and while logistics engineering does present a helpful management guide, the existing suite of material does not delve into much richness when considering 'live' sustainment operations.

Consider the following observations of the two key texts that have come to define this field – Blanchard, and Jones:

- They mostly focus attention on the design and development of the system, and how supportability is be planned for and accounted for, but very little on how to manage a system once it has entered into service.
- It follows a very US DoD-centric linear program lifecycle view (namely from program conception, to system manufacture, to disposal). It doesn't delve into the contractor/service provider view of how to organise and deliver on such a contract.
- They tacitly assume that the engineering organisation engaged in the development of a system will revert to a support mode. As this study suggests, this is not always straightforward, or even true. It doesn't account for the organisational complexity that occurs when such an engineering outfit is operating across development, production, product support, and operator support.
- They tacitly assume that there is only one customer for the system. This might be the case with some US DoD programs (such as F22), but generally there are many customers.
- They focus on the system, rather than the organisation(s) that supports the system. Support of the operator, as opposed to the system, is barely discussed.
- They only briefly touch on real-world examples, or issues – they're a reference text of processes, not a rich book of experiences.
- Overall, they look at the space from a product-centric worldview (e.g., follow the system through lifecycle), rather than from a customer or service-centric view (e.g., preparing and working with a customer organisation to operate a new asset).

As previously discussed, how logistics concepts are enacted is a more fruitful angle to consider. Concepts such as service-led projects and Complex Engineering Service Systems are models that this study seeks to understand more properly and help develop a management methodology for.

The disconnect between a product-centric and a service-centric view that focuses on providing for the business needs of a customer, albeit via a complex technical product, is a key driver for this study to address. Finding a more cogent expression of engineering in such a context is an underlying component of such a management methodology. Consider the view of Davis [76] who makes the point that "equating engineering with designing, building, or the like involves at least two mistakes" – both of technologists also involved with that pursuit, but also the wide range of activities that engineers are engaged in. Not all design and building work can be classified as engineering, and not all engineering can be filtered down to designing and building.

10.5 A near miss

Amid the military-focused nature of this chapter looking at logistics engineering to help generate availability and capability, there is something that has been subtly overlooked or taken for granted: safety and airworthiness. Yet, these are outcomes and properties that are essential for any aircraft operator. Whilst processes such as reliability management and maintenance management are significant contributors to safety goals, they're concepts that deserve closer attention before any comprehensive management methodology for aerospace Solutions can be fully pursued. This is the focus of the next chapter.

CHAPTER 11

Breaking Not-So-Bad

Managing Safety in Hazardous Industries

11.0 Safety management in safety-critical industries

Consider nuclear power, aviation, healthcare, rail, and submarining. These are the key sectors where mistakes cost lives[13], and where hazards are never far away. They are sectors for which the management of safety is paramount.

The field of *safety management* is a broad church, and whilst this study isn't primarily about safety management, it's inextricably linked. Thus, it's important to review at least some of the foundational concepts.

This 'safety primer' chapter seeks to cover:

- Definitions and characteristics of safety
- Key safety management concepts
- The idea of Airworthiness
- Key airworthiness concepts and management frameworks.

It's not intended to be comprehensive or to academic standards – the field is that broad, becomes complex very quickly, and is constantly evolving. There are many related, in-depth fields, too, such as risk management, tort and legal liability, quality management, and reliability engineering. However, it's a guide that will help the reader appreciate some of the complexity of the following chapters.

11.1 What is safety?

Most dictionary definitions of *safety* centre on a state in which people and property are free from harm, damage or risk (for example, Mirriam-Webster [181]). The ICAO echoes this view, stating that safety is:

[13] Sometimes slowly, sometimes almost instantaneously.

> The state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and safety risk management. [182]

However, such dictionary definitions are not overly instructive when it comes to understanding the nature of safety, an essential step before been able to manage it effectively. So, what other properities does 'safety' exhibit?

11.1.1 Of the mind

Safety is primarily a social and noetic construct [183], rather than purely a measurable outcome (for instance, fatalities or injuries per unit time). A study of the etymology of *safety* is revealing. The term comes from the Old French word *sauveté* meaning 'safety, safeguard; salvation; security, surety' – terms that have been adopted by technical domains, but that also have strong social and personal connotations. One of those terms, s*urety* is particularly illuminating, itself derived from another Old French word *seurté* meaning 'a promise, pledge, guarantee; assurance, confidence', and later from the Latin *securitatem* (the normative of *securitas*) meaning 'freedom from care or danger' [184].

The meaning of the term *safety*, as used in Western societies today, has slightly shifted from its roots to more of an *absence* of harm, rather than a *presence* of security and confidence – a nuance that some safety professionals open up for critique (see below). However, understanding this fundamental property of safety is important, as it can colour how safety professionals approach their work.

11.1.2 Safe & safety

Safety is not just about an absence of accidents or injury. For instance, an "unsafe operation" doesn't necessarily mean one where there is a spate of accidents – the operator can be operating at the margins and just be 'lucky'. On the converse, a reputable operator that operates to industry-leading standards (i.e., has exceptional *safety management capabilities*) can be distinctly 'unlucky' and experience a horrific event. "Chance does not take sides – it afflicts the deserving and preserves the unworthy" [185].

As James Reason [185] points out, safety is often defined and measured more by its absence, than its presence – yet, safety is truly concerned with a positive outcome, and a "safe operation" to do with the level of *safety management capability* possessed by an organisation.

11.1.3 An outcome

This gives rise to the idea that safety is not merely an absence or avoidance of 'bad things', but that it is rather the positive outcome of many things working together to produce it. Safety is an outcome – described as an emergent property of systems or complexity [183, 186].

Safety is the result (the emergence) of many complex, interacting elements. It's not merely the absence of things (including people) making errors; it's the active 'things going right' that ultimately produces safe outcomes. Thus, safety is not fully explained by a causation perspective where a predictable, linear chain of events, like Figure 23, explain a harmful event.

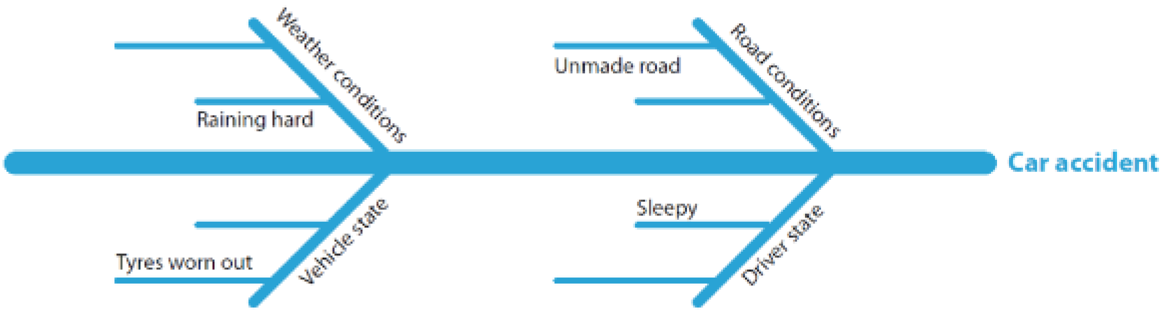

Figure 23: Safety, as viewed as a linear chain of events [187]

11.1.4 Safety is an emergent property of complexity

Instead, safety (or, 'a positive outcome') is the something that emerges because of many interacting elements and events that lead to a safe outcome. Whereas a linear approach tries to determine a root cause (and conditions) which causes the unsafe event, a complexity approach to safety suggests that even though the same root cause might be present in another situation, the outcome can be entirely different. Each event is unique, and the result depending on many transient phenomena [187].

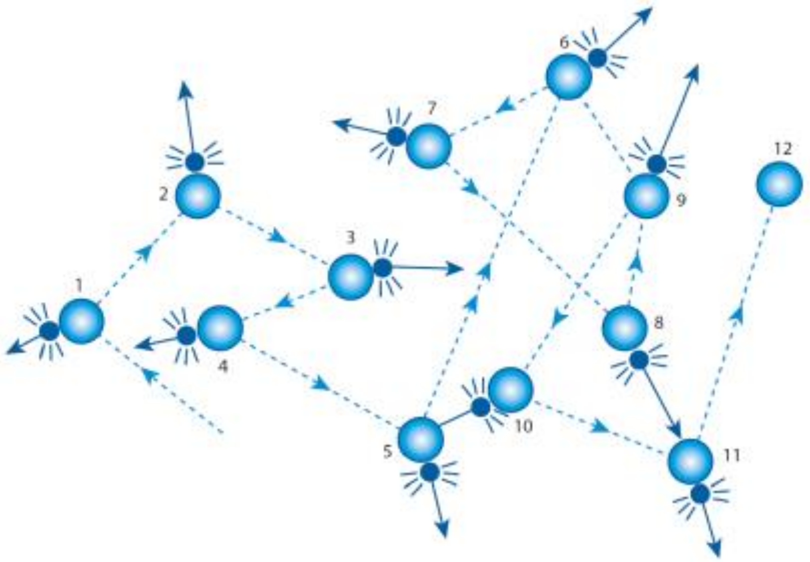

Figure 24: Safety, seen as an emergent property of complexity, rather than a blocked chain of events [187]

11.1.5 Unbankable

It follows that safety is not a 'bankable' commodity that can be stored up and used later [54], and as Reason describes, "there are no final victories in the struggle for safety" [185].

Rather, safety is the result of something far more dynamic and involving much effort. Weick & Sutclife [54] describes "safe reliable performance" as "a dynamic non-event – what produces the stable outcome is constant change, rather than continuous repetition. To achieve this stability, a change in one system parameter must be compensated for by change in other parameters". This leads to a trap, Weick

& Sutclife argue. “The problem is that when a system is operating safely and reliably, there are constant outcomes, and nothing to watch”. As Reason explains Weick’s idea:

> “safety is invisible in the sense that safe outcomes do not deviate from the expected, and so there is nothing to capture people’s attention. If people see nothing, they presume that nothing is happening, and that nothing will continue to happen if they continue to act as before. But this is misleading because it takes a number of dynamic inputs to create stable outcomes.” [188, 189]

To put it another way, “safety is no accident…”

11.2 The field of safety management

So, what is ‘safety management’? It’s a question not helped by the lack of a grand ‘unifying theory’ of safety. *Safety management*, as a field, is more of an applied discipline, more prescriptive than philosophical, although certainly not devoid of highly enriched research insights that form useful management interventions and techniques.

That been said, safety management is often expressed in the following ways:

- Safety management is generally accepted as efforts to achieve and maintain a condition and level of safety (where the level of safety (or safety goals) are defined in some way) [187]
- Safety management is enacted by applying of a set of principles, framework, processes and measures to prevent accidents, injuries and other adverse consequences that may be caused by using a service or a product [190]
- “Safety management involves managing your business activities in a systematic, coordinated way so that risk is minimised” [191].

What does cut through each of these definitions is a structured approach to managing safety – a management approach that built into the way the company is managed on a day to day basis.

11.2.1 Concept of organisational accidents

Recent intellectual efforts have focused on systemic factors that drive safety outcomes. Whereas previous foci have been on the technology and the performance of the individual, these recent efforts are focused on the organisational aspects of safety – the often hidden, but very real systemic issues that either lead to safe outcomes, or that could end up as an accident.

ICAO recognise that approaches in safety management (in the aviation context) have gone through an evolution, from the technical era, to the human factors era, and since the early 1990s, the organisational era [182]. Reason particularly focuses on the dynamics of what he terms *organisational accidents* [192]. They are “comparatively rare, but often catastrophic events that occur within modern complex technologies such as nuclear power plants, commercial aviation, the petrochemical industry, marine and rail transport, and banks… [They] have multiple causes involving many people operating at different levels of their respective companies…. [They] are a product of recent times or, more specifically, a product of technological innovations which have radically altered the relationship between systems and their human elements”.

Central to this concept of organisational accidents is the continual tension between what Reason describes as *Production vs. Protection*. Resources, effort and cost all have to be expended in delivering production (whether physical products, or service), as well as protection. However, too much expenditure on protection and the organisation goes into bankruptcy; too little, and it will likely experience catastrophe. Actions necessary to ensure safety are sometimes at odds with 'getting the job done' and can lead to a very plausible situation where corners are cut. It's this uneasy tension, Reason argues, that can facilitate a slide down a pathway to an organisationally-induced accident.

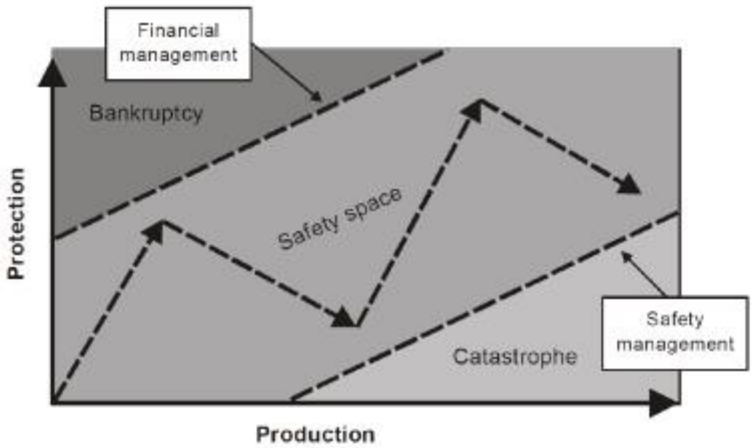

Figure 25: The protection-versus-production dilemma [192]

Reason also provides a wide-ranging analysis of the nature of organisational accidents, and means for managing and taming them. There is an emphasis on the human element in operating advanced technologies, how even well-intentioned defences can sometimes contribute to further safety degradation, and strategies for identifying and minimising errors by human actors. Central to this is the notion of *safety culture* (discussed shortly).

11.2.2 Safety Management Systems

Safety Management Systems represent a deliberate, structured, organised and integrated approach to managing the factors that impact safety. Its intent is to have safety matters managed as routinely as other aspects of the business, such as finance, customer service, or the supply chain.

Transport Canada describes an SMS as "a businesslike approach to safety – a systematic, precise and proactive process for managing safety risks [191]." In a similar vein, CASA describes it as a "systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures [191]." Rather than prescriptive regulations for every conceivable facet of an operation, regulators instead are mandating an *organisational safety management capability*.

It's difficult to pinpoint exactly who and where the term SMS was developed; however, it was not exclusively an invention by the aviation sector. The SMS concept has gained traction in rail, engineering asset management, general OH&S, and more recently in the healthcare sector. Nonetheless, its most prolific (and perhaps consistent) application is likely in the aviation sector [193].

It is perhaps better explained as being a s*afety management regime* – to describe it as a *system* is neither complete nor accurate. To term the concept as a 'system' can suggest:

- A limited, isolated, bounded and highly controlled activity - for example, an accounting system. However, it's one that is both divorced from 'how things really work' here, and from 'core business'
- Something more cold and mechanistic, rather than organic and living.

A SMS is not an operations or service-focused Quality Management System (QMS), even though the realm of procedures, audits, data collection and analysis, and continuous improvement is heavily drawn upon. It is the embedding of a *management methodology* and the raising and sustaining of a safety management capability within the company or organisation. Whilst regulations seek to make the elements of this capability explicit, visible and tangible, the ultimate intent is to make safety management an inherent part of a company's DNA.

Ideally, this safety management regime permeates the entire organisation – from the CEO, to the mailroom worker, but also from 'hard' safety measures (such as written procedures and data systems), through to very opaque, but very powerful aspects such as organisational culture and individual awareness. It's a deliberate act of the company becoming proficient at managing the factors that affect safety, and not just being competent at regulatory compliance.

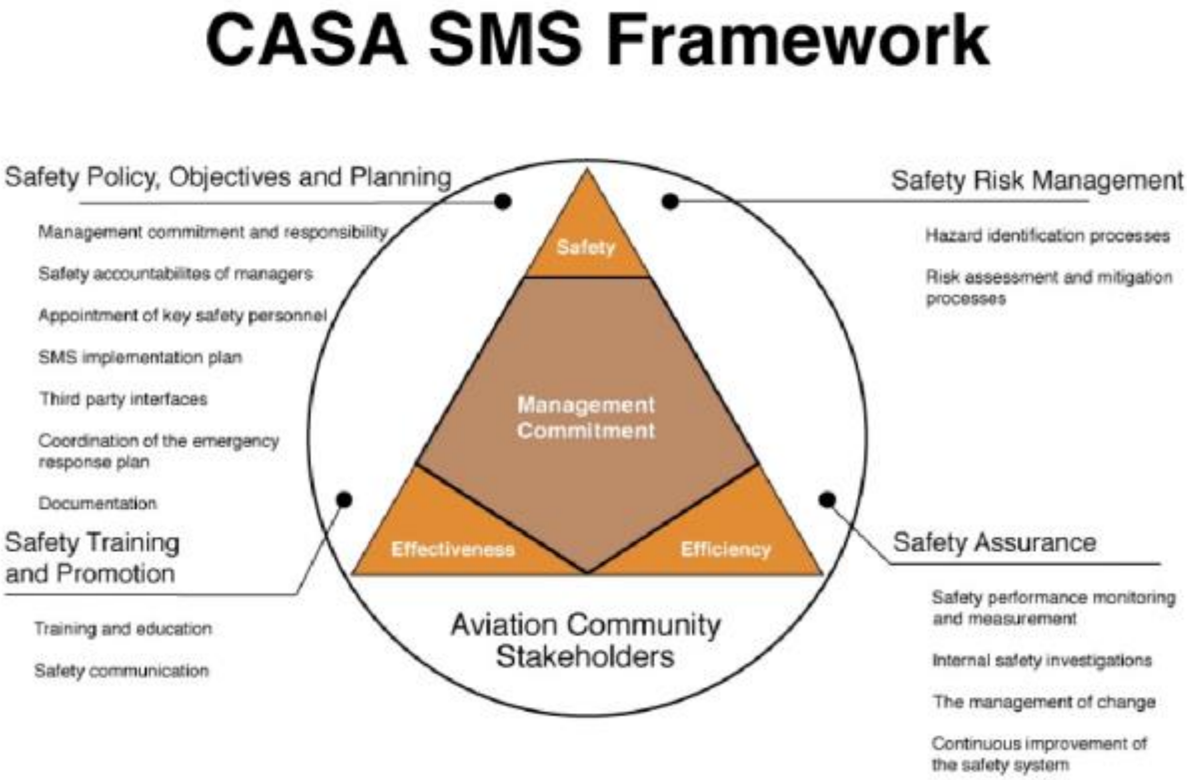

Figure 26: Key aspects of a safety management system as required by the Australian Civil Aviation Safety Authority (CASA) [191]

On a more prescriptive level, there are four major components to an aviation-standard SMS [182]:

- **Safety policy and objectives:** This includes safety performance goal setting, defining key policies, appointing the right safety leadership structure, and management setting the tone and expectations for safety across the organisation.
- **Safety risk management:** An effective safety management regime actively seeks out hazards in many ways, including data analysis, research, brainstorming, investigations, feedback, surveys and scenario-generation, and then analyses and evaluates the risks, before implementing risk treatments.
- **Safety assurance:** 'You manage what you can measure' is the management axiom. Monitoring 'safety performance', and investigating when things go wrong, is an essential element of managing safety.
- **Safety promotion:** Articulating a management expectation of safety is one thing; sustaining a persistent awareness, even fear of a negative safety outcome, requires training an organisation's staff, and constantly telling the 'safety story'. This includes promoting lessons learnt from safety investigations and re-emphasising the need for vigilance associated with known hazards. These are elements that contribute to building and sustaining a safety culture.

11.3 Safety culture

Safety culture is often referred to as the critical element or foundation on which all safety management efforts are based. It's the 'glue' – perhaps colloquially, the 'magic' – that brings alive an organisation's capability to proficiently manage safety.

Reason states that for a safety critical operation, there exists a "need for an organisation to inculcate and then sustain a healthy but intelligent respect for the hazards that threaten its operations …. [but that] several power factors act to push safety into the background of an organisation's collective awareness, particularly if it possess many elaborate barriers and safeguards." Hence, Reason argues, that 'engineering a safety culture' is a critical aspect to an organisations' safety management capability, stating an "ideal safety culture is the 'engine' that drives the [organisational system] towards the goal of sustaining the maximum resistance towards operational hazards, regardless of the leadership's personality or current commercial concerns [188].

Hudson [194] is credited with articulating a continuum of an organisation's safety culture. An organisation with a poor safety culture is described as being *pathological*, and an organisation that has a highly-evolved safety culture as having a *generative* safety culture, where safety is core business.

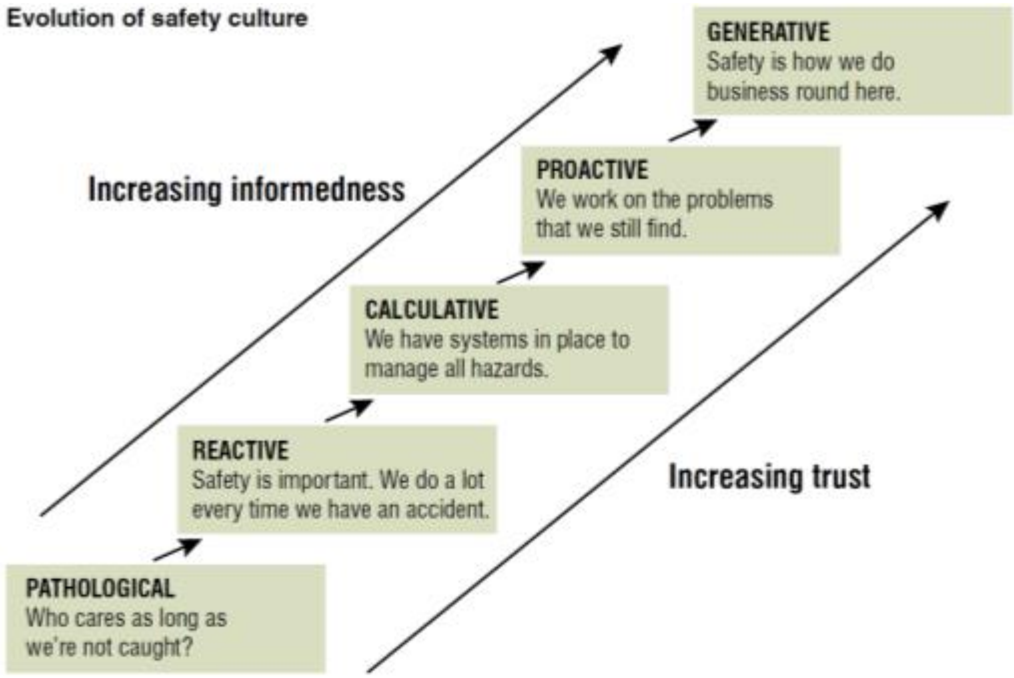

Figure 27: Hudson's continuum of safety culture [195]

Perhaps more broadly, Hudson's continuum is an instructive model that describes the maturity and comprehensiveness of an organisation's safety management capability. A calculative organisation, for example, treats safety primarily as an "add-on function and a mechanical application of a management system" [195] – it is a combination of leadership, other cultural elements such as beliefs, as well as tools and processes that support or reinforce that cultural piece.

Whilst Hudson's model is useful for describing organisational safety management capability, work by Reason [185, 188, 192] adds some specificity to the issue, identifying various elements of an ideal safety culture. They include several sub-cultures:

- **A learning culture:** An organisation must possess the willingness and the competence to draw the right conclusions from its safety information system and be willing to implement major reforms.
- **A reporting culture:** To enable an organisation to have an effective safety information system, and to garner effective insights from that program, good quality and consistent data needs to be supplied. This requires an organisational climate in which people treat the reporting of their errors and near-misses as the norm.
- **A just culture:** Further to support a reporting culture is a requisite atmosphere of trust. A just culture promotes an environment where people are encouraged to report mistakes, errors and other safety-essential information, whilst being cognisant that there is a line between acceptable and unacceptable behaviour. It's neither a 'blame culture', nor a 'non-blame' culture, but rather a common understanding that there are some acts, such as willful violations, that must be dealt with, whilst mindful that human performance is never a consistent thing.
- **A flexible culture:** An organisation that can adapt itself to critical situations, often by adopting a temporary, flatter organisational structure where expertise is differed to, rather than hierarchical rank – and subsequently resume the 'usual' formal structure once the situation has passed.
- **An informed culture:** A consequence of possessing a strong learning, reporting, just and flexible culture, is an informed culture. This is where all those who are involved with a safety-critical operation – whether as a manager, an operator, have a deep understanding of the factors that determine and affect the safety of the operation as a whole. These include human, technical, organisation and environmental factors.

It is this *informed culture* that matters. As Reason explains, referencing the production-versus-protection struggle:

> "It is production rather than protection that pays the bills … Moreover, the information relating to the pursuit of production goals is continuous, credible and compelling, while the information relating to protection is discontinuous, often unreliable, and only intermittently compelling (i.e., after a bad event)."

A culture that is informed – one that is deliberately seeking out information pertaining to the safety of its operations – is one that will be mindful of its production strengths, but also mindful of its potential for protection weakness. It's a hallmark of an operator known as a High Reliability Organisation.

11.3.1 Asset management cultural framework

To quickly continue illustrating the universal tussle between production and protection is a thought-provoking framework taken from researchers in the Engineering Asset Management domain. Whilst the framework is perhaps not fully developed, it is an instructive view of the cultural drivers of organisations that operate advanced, capital-intensive assets, such as aviation and defence.

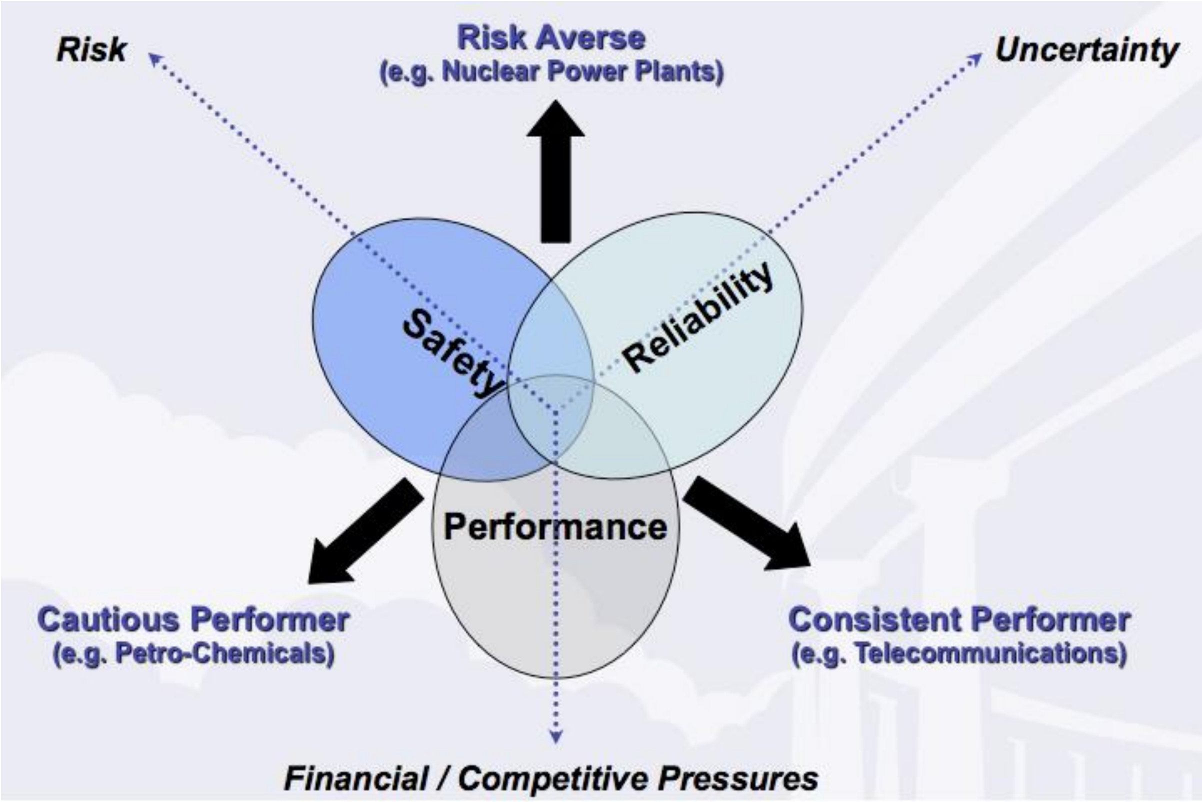

Figure 28: Asset Management cultural framework [196]

Murphy & Jill [196] assert that there are three key operational elements that Engineering Asset Management organisations value: asset safety, asset reliability, and asset performance, with ‘performance’ recognised as a union of availability, utilisation, and cost minimisation. Their framework seeks to visualise the prospective tensions between these different organisational priorities, identifying three organisational personas that tend to emerge in the engineering asset management domain.

These three personas are:

- **Risk Averse:** organisations, such as nuclear power stations, where safe and reliable operations must trump all else.
- **Cautious Performer:** organisations where there still exists great potential for catastrophe, but where the rewards of successful operation are high and very desirable. Strong safety management capabilities help manage the risk, whilst also ensuring a highly productive outcome. Petrochemical firms and military units tend to meet this description.
- **Consistent Performer:** organisations where, in the normal course of business, are not likely to face the potential for catastrophic circumstances where people’s lives are at stake. Rather, the engineering workforce’s culture is built around extracting high levels of utilisation and financial value from the asset. Telco providers and some utility providers (namely water) tend to fall into this category.

Whilst this framework isn’t perfect, nor focuses exclusively on safety (the focus of this chapter), it does illustrate that safety doesn’t exist in a vacuum. It follows that, for organisations operating or supporting aircraft, a thorough cultural model is necessary to manage safety alongside other important priorities –

even if such organisations might consider themselves somewhere between a Risk Averse and Cautious Performer.

11.4 High Reliability Organisations

Building upon the concept of safety cultures is perhaps one of the most comprehensive archetypes of an organisation that has a strong safety management capability: the High Reliability Organisation, a concept made popular by Weick & Sutcliffe [54]. They an organisation who live with a persistent suspicion and vigilance, always living 'on edge', believing an accident is never far away.

There is some dispute about the academic legitimacy of the concept – in reality, no company or organisation exists to the purity that is expounded by the authors. However, it still serves as a very useful and pragmatic template of what to look for in an organisation that operates to high levels of reliable, safe performance, even when operating in a highly hazardous environment or line of activity.

The major argument is that these organisations have a core strength in *managing the unexpected* – the key 'secret ingredient' for consistent, safe performance. Weick & Sutcliff add to this key contention by arguing that "good management of the unexpected is *mindful* management of the unexpected".

They identified five traits of such organisations which enable them to be extremely reliable in their operations.

1. **Preoccupation with failure:** HROs are obsessed with learning about, and from, failure. They recognise that even the smallest of failures are opportunities to learn about potential disasters, and how to be alert for the warning signs, and how to prevent catastrophe. They live with a conscious knowledge that not all failure modes have been experienced or exhaustively deduced. As such, they foster an environment that encourages (rather than discourages) error reporting, and learning. HROs also live with the conscious knowledge that success is blinding, raises complacency, and narrows perceptions, thus providing a temptation to reduce safety margins, or at the very least, assume current procedures are adequate.

2. **Reluctance to simplify:** They accumulate unnoticed events that are at odds with accepted beliefs. Rather than deferring to static models of past experience or interpretation of events, HRO's nurture a discipline to always be enhancing their understanding of their environment, and building newer and more complex mental models of circumstances and events, challenging the status quo of what they understand. What may seem like a common symptom may have different root causes – ones that could cause a disaster.

3. **Sensitivity to operations:** HRO's actively ensure that there is no disconnect between management and the 'front line'. This helps aid building one picture of the true state of the organisation, rather than different interpretations at different levels or in different sections

4. **Commitment to Resilience:** HRO's are not organisations that are considered error-free, but rather have the capability to detect, contain and bounce back from errors as quickly as possible. This includes improvising workarounds, where appropriate, to ensure a consistency of functionality and safety. Where other organisations view workarounds as being a source of inefficiency or deviation from procedure, HRO's see workarounds as adaptations to the evolving environment and an effective strategy for ensuring continuous, safe operations.

5. **Deference to Expertise:** Rather than centralising all decisions, HROs actively seek out experts in the organisation to make critical decisions, often those who are at the coalface. Rather than

trusting a given procedure for a generic circumstance, this discipline builds upon the reluctance to simplify that HRO's demonstrate.

Perhaps one of the most striking traits of a High Reliability Organisation is that they live with a "chronic fear of potentially killing people". As such, this particular organisational archetype is one pertinent example of the type of organisation any firm engaged in aircraft support should consider and potentially be modelled upon.

11.5 The field of airworthiness

11.5.1 Definitions

Despite being a concept that is extensively referred to in regulations and aviation standards, there is a peculiar lack of formal definitions of *airworthiness*. Even in ICAO's Airworthiness Manual [197], there is yet no formal definition. However, there are some entities which provide definitions that enjoy widespread acceptance. They define *airworthiness* as:

- "Fitness for flight operations in all possible environments and foreseeable circumstances for which aircraft or device has been designed [198]"
- "The ability of an aircraft or other airborne equipment or system to operate without significant hazard to flight and cabin crew, ground crew, passengers, cargo or mail (where relevant) or to the general public and property over which such airborne systems are flown [199]."
- "The ability of an aircraft or other airborne equipment or system to be operated in flight and on the ground without significant hazard to aircrew, ground crew, passengers or to third parties; it is a technical attribute of materiel throughout its lifecycle [200]."
- "The condition of an item (airplane, airplane system, or part) in which that item operates in a safe manner to accomplish its intended function [201]."
- Refers to an aircraft being 'fit to fly' in all environments and circumstances for which it has been designed and certified [202].

For the purposes of this safety primer, these definitions are adequate; however, there are deeper questions to be asked about the concept of airworthiness and what its true nature is. This is unpacked in more detail in Chapter 27.

11.5.2 A brief history

Whilst the military have generally been the pace-setter for aviation technology, it is the civilian world which has led the way on airworthiness and safety management [202]. The first official requirement for certification of an aircraft goes back to the *Air Commerce Act* of 1926 in the United States, and it has remained as the conceptual foundation for airworthiness management in the United States and beyond. Other nations, such as France and the UK also developed requirements and standards, soon after. However, there was no international harmonisation of rule-sets and standards – perhaps not a pressing issue in the early decades of aviation, but as aviation technology began to 'shrink the world,' a more global approach was called for.

Towards the decline of World War 2, many nations recognised that the rapid advances in aviation technology used for the military effort would eventually be turned towards civil and air-transport operations and that a mechanism for globally harmonising standards, practises and regulations was necessary. This was the impetus for *The Convention on International Aviation*, signed by 52 nation states in Chicago on 7 December 1944. The *Chicago Convention*, as it's known, defined the international system of international aviation and air transport, including the management of airspace, customs, taxes, communications, and flight plans, but also outlined standards each signatory state should seek to codify in their national regulatory environments. The Convention also called into being the *International Civil Aviation Organisation* (ICAO) – what is now the United Nation's agency for fostering and developing international air transport.

The standards in the Convention are included as Annexes, and cover standards (as opposed to legal requirements) for flight operations, training, licensing, maintenance, and airworthiness control/management. *Annexe 8* to the Convention covers the Airworthiness of Aircraft.

11.6 Key airworthiness concepts

Most foundational airworthiness concepts find their origin from Annex 8, and from its spawn the *ICAO Airworthiness Manual [197]*. This Manual lays out a framework for member states to use in the development of their own framework of airworthiness regulations and requirements. The Manual includes standards and recommended practises covering:

- Type Certification
- Maintenance Review Board
- Production Approvals
- Certificates of Airworthiness
- Continuing Airworthiness
- Changes to Type Designs
- Modifications and Repairs
- Maintenance Organisations.

Each of these areas plays an important part in ensuring a globalised aircraft airworthiness system, and they are all essential for controlling the technical integrity of aircraft. They form an instructive list of concepts to secure an understanding of how airworthiness is managed.

They're roughly broken into two 'genres' – initial, certification-related airworthiness, and continuing/in-service airworthiness concepts. These concepts make up the framework of airworthiness management activities; however, further explanation is provided shortly about *who* is responsible for what activities.

11.6.1 Initial/certification airworthiness concepts

Before an aircraft can be put into service, it must demonstrate its inherent suitability for flight. This is through a rigorous and formal certification regime.

11.6.1.1 Type Certification

One crucial aspect of controlling airworthiness is through defining the minimum design standards for aircraft and ensuring that aircraft are designed to those standards. These standards have often been hard won – modern standards are an evolution of early airworthiness standards, changed, iterated and reviewed often in the light of appalling accidents.

It is these codified, determinant design requirements which then form the basis of the evaluation and validation effort undertaken by certifying bodies prior to the aircraft design been issued with a Type Certificate – an approval from the certifying body that the aircraft design is considered to be acceptably safe for a given operation. Included in this codified and detailed scheme are requirements for control, structural strength and reliance, as well as often a requirement to demonstrate, by analysis as well as test, the reliability of the aircraft system.

However, a TC does not certify individual, physical aircraft. The approval is against the *design*, or in other words, the template to which other aircraft are built.

11.6.1.2 Production Approval

Before an aircraft manufacturer can assemble approvable aircraft, they must gain a production approval. The Production Approval means that the organisation who performs production has adequate systems, processes and quality control to ensure that what is produced confidently, reliably and consistently replicates the type design data, including material specifications, dimensions, following assembly instructions, and verification of the assembled item against the design data.

11.6.1.3 Certificate of Airworthiness

Once an aircraft has completed production, to be accepted into a State regime's airworthiness system (e.g., to export the aircraft from the manufacturing nation to the customer's nation), the aircraft must gain a Certificate of Airworthiness. This is to certify that the actual aircraft is a true, faithful and approved 'copy' of the aircraft design, but also that local airworthiness requirements (e.g., for role equipment or cabin furnishings) have been embodied on the aircraft. It means that individual, physical aircraft meets the standards set by the nation or airworthiness regime. The aircraft cannot enter service without reaching this milestone.

11.6.2 Continuing & in-service airworthiness

This safety primer chapter isolates continuing airworthiness because it is perhaps the more intriguing element to the overarching field of airworthiness. It's where things get a little messier, blurred, and perhaps where the insurers of aircraft manufacturers pay most of their attention. Having a design that has proven its salt against a codified standard is one thing, but does that mean the aircraft is actually 'safe'?

Continuing Airworthiness is routinely defined as:

- All the processes ensuring that, at any time in its life, an aeroplane complies with the technical conditions fixed to the issues of the Certificate of Airworthiness and is in a condition for safe operation" [203]

- “Covers all the processes ensuring that, at any time in their operating life, all aircraft comply with the airworthiness requirements in force and are in a condition for safe operation” [197]
- The activities necessary to ensure that the aircraft remains airworthy throughout its design life [202]

It’s here that a distinction must be drawn between *continuing airworthiness* and *maintenance*. As Baines & Simmons [180] illustrate, they are two distinctly different, albeit highly related activities. They state that, among other things, maintenance is concerned with:

- Confirming the realisation of the inherent safety and reliability levels of the aircraft (as determined by design)
- The physical act of restoring product safety and reliability to their inherent levels should deterioration occur
- Obtaining information required for re-design in light of system inadequacies
- Accomplishing these activities at a minimum total cost.

Whereas the realm of maintenance is more visible (e.g., hangars, tools and maintenance manuals), the realm of continuing airworthiness is somewhat more noetic – that it is more of the mind than the hands. The ATSB touches on this, articulating the concept of *continuing airworthiness assurance* – “the confidence that there are robust systems in place to ensure that the continuing airworthiness status of the aircraft is *known* at all times [Emphasis added] [202].”

So, what does an effective continuing airworthiness regime involve? ICAO identifies in section 4 of their Airworthiness Manual [197] the main/minimum ingredients:

- A clear, capable organisation responsible for the type design
- The implementation of a structural integrity programme by the type design organisation
- The effective exchange and use of continuing airworthiness information – across a network of actors, including responsible states (regulators), type design organisations, and operators
- Methods of ensuring authenticity and serviceability of aircraft parts.

In practise, these requirements are better expounded in an investigation report by the ATSB where they identify eight principal continuing airworthiness activities [202]. Whilst not all these principles are strictly enshrined in law, it’s an enlightening piece that highlights the global system of continuing airworthiness in the civilian context at least. It’s a system, however, that’s increasingly informing military airworthiness agencies, and thus is an instructive framework to look at.

These 8 activities are:

- Aircraft design validation
- Recommended Maintenance Program
- Recommended Inspection Program
- Safety-critical inspections, maintenance and time-lifed components
- Maintenance practises and processes for the accomplishment of maintenance.
- Advisory Continuing Airworthiness Information
- Mandatory Continuing Airworthiness Information
- Defect Reporting and operational experience.

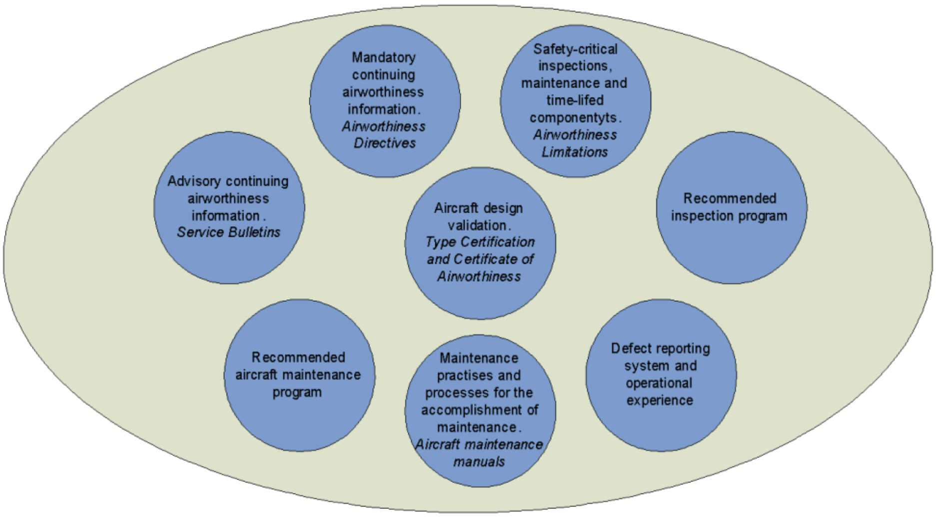

Figure 29: The eight principal continuing airworthiness activities [202]

11.6.3 The eight principal continuing airworthiness activities

11.6.3.1 Aircraft design validation

A critical foundation of any continuing airworthiness effort is ensuring that the aircraft (and subsequently fleet of aircraft) meet the right codified standard. This means the aircraft design is certified (Type Certification), and that the physical aircraft is validated as a true copy of that design, with the necessary modifications to meet local standards (Certificate of Airworthiness).

11.6.3.2 Recommended maintenance/inspection program

The manufacturer generally provides a recommended inspection and overhaul/maintenance program. In the civilian world, the manufacturer is required to provide “Instructions for Continuing Airworthiness” which constitutes a recommended schedule of tasks, and instructions for how to carry out those tasks.

The two concepts – inspection and maintenance – are split out to indicate that much of the reason for the hands-on physical effort is to verify, on some periodic basis, that the aircraft’s state of health is still acceptable. The aircraft may not need any rectifying once inspecting; however, validation of the aircraft’s state of health is an important task.

Modern transport-category aircraft have a maintenance program derived from a methodology known as MSG3, similar to the Reliability-Centred Maintenance (RCM) concept. In the aviation context, the manufacturer establishes a Maintenance Review Board (or MRB) which is made up of representatives of the OEMs, the certifying authority, and the nominated customer-operators. The MRB uses the MSG3 methodology to produce and release an MRB Report which specifies the identified maintenance requirements for the aircraft in the expected course of operation. It is from the MRB Report that the manufacturer then releases a Maintenance Planning Data (MPD) document – the recommended program and schedule of maintenance tasks which generally forms the basis of an operator’s specific maintenance program.

11.6.3.3 Safety-critical inspections, maintenance and time-lifed components

Depending on the regulatory regime, recommended maintenance programs are just that – recommended. Whilst required by civilian authorities, they're only *accepted* by the certifying authority, not *approved* (and thus may not have the same rigor of validation as the approved aspects of the design). These recommendations generally form the basis of an approved maintenance program by the regulatory authority oversighting the aircraft operator (not manufacturer), but this 'recommendations approach' provides some flexibility in developing a suitable program afforded by the high levels of redundancy built into the aircraft.

However, there is some maintenance related actions that need to be strictly adhered to and for which failure to do so may be fatal. In civilian parlance[204], there are three main restrictions that form part of the certification of the aircraft:

- **Airworthiness Limitations:** mandated life-limits or inspection periods of structural items having been identified as critical elements in a fatigue or damage tolerance assessment
- **Critical Design Configuration Control Limitations:** requirements to maintain at high standards design features aimed at reducing or mitigating flammability and/or ignition means on the aircraft. This includes wire separation, lightning protection, and fuel-tank aspects
- **Certification Maintenance Requirements:** a required scheduled maintenance task designed to detect significant latent failures that, when combined with one more other specific failures or events, would result in a hazardous or catastrophic condition.

The derivation of these requirements is similar to a process used to determine the recommended maintenance program. However, these are hard-and-fast requirements that must be adhered to.

11.6.3.4 Maintenance practises and processes for the accomplishment of maintenance

Where the inspection and maintenance program specify what and when, manufacturers must also specify how maintenance tasks are to be performed. This is generally in the form of designated Task numbers in the Aircraft Maintenance Manual, with accompanying job cards for mechanics to work through step-by-step.

There are often also standardised maintenance practises for materials and technology used on the aircraft, such as structural repair techniques, wiring inspections and repairs and specific substances used around the aircraft. Feeding into this regimen of aircraft specific practises is a type-based training program that expounds the nuances and particularities of an aircraft type design.

11.6.3.5 Advisory continuing airworthiness information

Service Bulletins (SBs) & Service Letters (SLs) are type-specific documents issued by the aircraft, equipment or engine manufacturers and may address airworthiness and safety issues (such as recommended inspections, repair or rework), but may also be service advice that has economic or logistics relevance (such as updated components). Action by the operator is generally on a voluntary basis. Whilst application is voluntary, they are "approved" in that the type design organisation that releases this information has undertaken the necessary engineering work and clearances for that information to be safely embodied onto the aircraft. It is design data, and forms a part of the certified aircraft design (even if it's not adopted).

In a hierarchy of documents, Service Bulletins tend to override Service Letters in importance. SBs contain specific actions, procedures, and instructions for carrying out a task. An SL, however, tends to provide context, extra details on an issue (potentially for which there is not a viable solution if the issue is minor), highlight reported unsafe practises by other operators, or provide extra guidelines or advice for carrying out a maintenance procedure.

11.6.3.6 Mandatory continuing airworthiness information

An Airworthiness Directive is a legal document issued by an airworthiness authority to aircraft operators that stipulate mandatory safety-rectification actions. ADs are released whenever an unsafe condition exists in an aviation product, and describe the unsafe condition, the applicability of the AD, any potential operating limitations, and deadlines for completed action. In the civilian world, many ADs reference a manufacturer SB and make embodiment mandatory.

11.6.3.7 Defect reporting and operational experience

The global, civilian continuing airworthiness system relies on the free exchange of safety information, including back from the field and into manufacturers, regulatory authorities and other essential stakeholders. ICAO Annex 8 sets the global standard for this regime, calling on member States to ensure "there exists a system whereby information on faults, malfunctions, defects, and other occurrences which cause or might cause adverse effects on the continuing airworthiness of the aircraft is transmitted to the organisation responsible for the type design of that aircraft". Airlines are required to deliver in-service information to the aircraft manufacturer to permit global fleet data analysis. From this analysis, specific safety action, such as SBs, and ADs, can be promulgated.

11.7 Who is responsible for airworthiness?

The previous section focused on key airworthiness concepts; but who is responsible for them? In the civilian context at least, aircraft operators such as airlines are responsible for the airworthiness of their aircraft; however, much of the continuing airworthiness efforts are actually held in the domain of the aircraft manufacturer. Thus a detailed review of the specific allocations of responsibilities involves some detail and finesse; thus this section sticks to key roles and allocations only.

11.7.1 Continuing airworthiness activities in the operational environment

A concept not readily conveyed is the difference between an organisation engaged in continuing airworthiness and one engaged in maintenance. Whilst the ultimate goals and objectives are very much aligned, each organisation has a different set of functions. In more recent times, regulations have been drawing a clearer distinction between the two units that might exist in the same company (primarily via CAMO regulations published by EASA).

There are some areas of responsibility that have been left out – most notably, approved engineering organisations that can devise repair schemes, or organisations who may undertake modifications to an aircraft (either individually, or to the design). These form part of a strict regime that restricts the embodiment and use of design changes that carry an official approval. However, they are beyond the scope of this brief.

11.7.1.1 Continuing Airworthiness Management Organisation concept

This has been achieved by various civil regulators through the concept of the CAMO, or Continuing Airworthiness Management Organisation. Such a unit is known by other names, such as Approved Engineering Organisations, or as Maintenance Control & Airworthiness groups.

Despite the terminology, they are a clearly designated group, attached to an operator, who holds a clear line of responsibility and authority for the airworthiness control and management of a designated fleet of aircraft. This specific focus contributes to a detailed and precise control of individual airframes and their own inherent, individual state of airworthiness. Whereas manufacturers look to the health of the *design*, CAMOs tend to look to the health of *individual aircraft* and a defined *fleet*.

Each aircraft has their own unique story, such as incidents, damage, or supply issues at a particular point in time. These are parameters that need individual attention to ensure the continued airworthiness of that particular aircraft. In addition, unique factors, such as local climate/environment, can alter the profile of an entire fleet – for example, close proximity to seas and oceans can increase the rate of corrosion across a fleet of aircraft. This is one reason why a fleet-wide approach to airworthiness is also critical.

Whilst there are some important differences, much of the Embedded Engineering Function concept is based on the CAMO concept. Primary differences are found in that CAMOs both determine and dictate work to be performed on an aircraft as well as the scheduling of that activity; in contrast, the EEF is primarily concerned with the determining and dictating piece. It's a theme discussed more in Chapter 25.

11.7.1.2 Aircraft maintenance organisations

An approved maintenance organisation, repair station, or maintenance provider is another clearly identified group that performs the physical act of carrying out maintenance. Whereas the CAMO is responsible for planning, reviewing information, and controlling the activities that achieve aircraft airworthiness, the maintenance provider is responsible for executing the maintenance tasks as directed by the CAMO.

Depending on the regulatory regime, the maintenance organisation does not have to be a part of the operator entity, giving opportunity for the physical work to be outsourced (under CAMO supervision and oversight).

11.7.2 Continuing airworthiness activities by the Type Certificate Holder

Once an aircraft has been Type certified, the certifying regulator generally will require a regime to be established inside the company to manage the ongoing airworthiness management of the type.

Whereas maintenance organisation regulations can be extensive, intriguingly, the requirements for manufacturers engaged in continuing airworthiness activities are not significant by comparison, a point raised in a report by the U.S. National Research Council [205]. Nonetheless, requirements for this program do exist, and take on different shapes and sizes, depending on the jurisdiction. In the civilian world, the certifying authority tends to require:

- A reporting and analysis process of in-service information and experience
- A process of producing and amending 'approved data' such as SBs, including a proper engineering process and/or structure
- Means of communicating changes to operators.

Some military regulators, however, tend to be a little more prescriptive, some requiring the formation of a System Safety Program. DGTA views this as:

> "The application of engineering management principles, criteria and techniques to optimize the safety of a 'system', within the constraints of operational effectiveness, time and cost throughout all phases of the life cycle…In a practical sense, an engineering risk management process designed to assure that the probability of detecting hazards inherent in the system is maximized through its Life of Type [206]."

This program is built on-top of the system safety assessment, or in some instances, a safety case. The system safety assessment is a rigorous analysis built on reliability engineering principles, formally determining the calculated inherent reliability of the aircraft design. The civilian parallel is often referred to as the "1309 analysis" – a technique based on FAR25.1309 that requires a full reliability analysis of the design, to prove by analytic techniques that the aircraft possess inherent, minimum reliability levels.

In a similar vein, a system safety case is a structured argument that argues that the aircraft design is safe. It may use more than a systems analysis approach, using other arguments such as standards used, the competence of the organisation who designed the aircraft, and the processes used for design. In some instances of highly modified aircraft (such as the Nimrod Mk.4 in the UK), the safety case may use the argument that the aircraft already complies with a particular standard, and focuses system safety management efforts around the modifications program and the hazards it may introduce to the updated design. As a significant investigation into a catastrophic loss of an aircraft in 2006 demonstrated [207], sometimes these safety cases can be flawed if not applied with sufficient rigor.

The safety case presents the stated safety and risk aims set at the outset of the development effort, presents the findings of the safety argument, and confirms if whether these aims were attained. The intent is that this safety case report is backed up by a body of evidence to prove its claims.

A true *system safety program* is thus a body of ongoing work that starts with the development of the aircraft and is subsequently revisited throughout the life-of-type. It's an ongoing process of undertaking reviews of in-service experience and information, logging and managing hazards, and reviewing safety performance.

11.8 Hang on

This briefing chapter has covered a lot of ground, from examining what is safety, to organisational archetypes useful in understanding how to manage safety, to key airworthiness concepts. But while this chapter has given an overview of airworthiness as it's conventionally understood, it's a complex field that could be more fully thrashed out.

For instance, what is the relationship between airworthiness and a more sophisticated understanding of safety? What is the mental or logical basis of airworthiness management, as if it were derived from first principles[14]? And just because something is certified to a codified standard, does it always mean it's safe?

These are questions that are considered in more detail in Chapter 27.

[14] Much of airworthiness management is about activities and processes – so what's the thought process that's involved?

Part III

Learning from real life cases

CHAPTER 12

The Power of Case Studies

12.0 Lessons from the line

As enlightening as exploring concepts such as service, logistics, and safety management might be, they only become valuable when used to understand and operate in the real-world. The converse is also true – it is lessons from practical experience which make for the most enriching of learning.

This report delves into two key case studies to glean real-life insights and lessons which can aid practitioners to think about the Complex Integrated Solutions concept, particularly in the aviation or safety-critical industrial contexts. It's these insights that can help generate a more appropriate management methodology for the Solutions business activity typology.

Both case studies use pseudonyms to de-identify the organisations, along with carefully removing other forms of information to obscure identification of the parties involved. However, they are two very real examples, being:

- The performance-based availability-driven sustainment program of a fleet of advanced jet trainer aircraft for a modern Western Airforce customer
- The change-management efforts of the Engineering & Maintenance Group within a modern airline operating a large fleet of narrow-body aircraft.

This introductory chapter provides some context on why case studies are an essential part of this broader study, helps set the scene for the case studies to be examined, and equips the reader with a map to navigate through the next ten chapters.

12.1 The case study approach

12.1.1 Why case studies?

Case studies are a leading research design of choice for qualitative and constructivist researchers. The approach allows certain freedoms in the research effort, such as not placing artificial limits on the unit to be analysed, and that the case study method is focused on human activity in the real-world. As such, the case study method is often described as a form of the exploratory research genre [208, 209].

12.1.2 The selection of these case studies

There are numerous programs and examples, as referred to in Chapter 2, of performance-driven sustainment programs across the world. So why these two, and only these two, selected?

Namely, because of access and opportunity. These case studies represent some unprecedented access into two live sustainment operations. This includes access to privileged and confidential commercial information about its activities and affairs that could give a competitor an unfair advantage. Thus, identifying suitable operations, earning the trust of senior management, and probing for information and insights typically restricted to internal discussions only was a delicate challenge. Thus, only two operations were examined (albeit with significant detail), both due to opportunity, but also to retain trust during the investigation period.

They were also cases that fall under a category identified by Otley and Berry [210]. They describe the type of case study that arises by chance whereby circumstances permit access to an opportunity to examine a phenomenon and suggest that although the study may be limited to a few aspects of organisational life, the results can be incredibly stimulating and original. This has certainly been the experience in both cases.

12.1.3 Findings, not just results

These case studies are more a raw data ‘dump’ or unframed description of the case study organisations at the time(s) of research. Rather, they represent findings of a semi-structured nature.

Although not analysis, discussion or conclusions, these findings are based upon numerous raw data sources, themselves disjointed collections of data. To present these case studies, the author has had to take this data, to break it down into more manageable concepts, and then re-order it to enable a more coherent presentation of information and facts that pertain to the case.

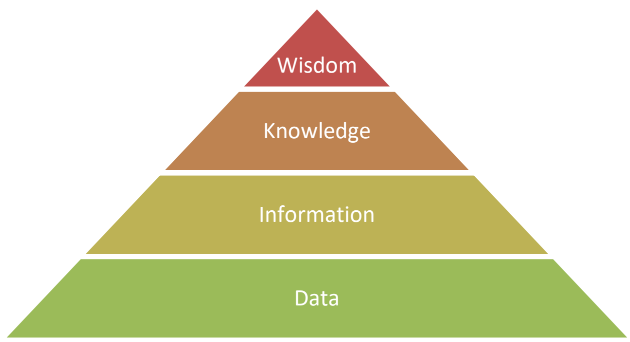

Figure 30: Schema depicting the relationship between data, information, and knowledge. These case-study chapters’ presentation of ‘findings’ artificially sits in-between information and knowledge.

These findings are derived from three principal sources of case study material:

- Analysis of internal documents and publications (equating to exposure to quite a sizeable quantity of proprietary information;
- Workshops with key Solution personnel (both provider and customer); and,
- Publicly available information pertaining to these operations (of course, these sources are not referenced to maintain corporate anonymity).

These findings, presented in narrative form, constitute an informed journey seeking to unearth unique insights of the Complex Integrated Solutions concept, based along broad themes. This is in pursuit of understanding the nuances of managing a CIS program, and garnering insights about the unique role engineering plays in such an evolutionary business space.

12.2 Case study 1

12.2.1 Key players

This case study sets up a fictitious world (as presented in Figure 31) to show the challenges of geography and to reflect a global nature of the aircraft program, without disclosing the customers and firms involved. At the centre of this Complex Integrated Solution narrative is the New Aragon Air Force, or NAAF, who transition across to a new jet fighter trainer called the *Milvus*. The Milvus is built by the global aerospace & defence conglomerate *DefTech Global* which is based in the nation of *Essenheim*. However, DefTech has operations in many localities around the world and has a sizeable operation in New Aragon which is referred to as *DefTech New Aragon*.

Figure 31: The fictitious world of the first case study [http://opengeofiction.net/]

Figure 32: New Aragon Air Force insignia

Figure 33: The Milvus jet-fighter trainer aircraft [Of course, this is the EADS Mako aircraft that never flew; *Milvus* is a pseudonym for a real jet fighter trainer aircraft]

As both enterprises are extensive (>70,000 staff) with a significant diversity of programs and activities, it's important to focus on the key divisional players for this case:

- Within DefTech New Aragon:
    - The Solution Delivery Group – the organisational unit that holds the Solution contract and conducts sustainment/support operations
    - The Engineering Unit (the Embedded Engineering Function (EEF)) within the Solution Delivery Group
- Within DefTech Global
    - The Type Design Group (TDG) within the Military Aircraft Division
- Within the New Aragon Defence Department:

- The two front-line training NAAF Squadrons (the 'customer-operator')
- The Defence Contract Management Agency (DCMA) responsible for the performance of the contractor and (traditionally) the administration and upkeep of the aircraft fleet
- The Defence Aviation Safety Regulator (DASR) that has responsibility for laying down and oversight of Defence airworthiness[15] regulatory standards.

DEFTECH Global

DEFTECH New Aragon

Figure 34: The logos of the DefTech Global and DefTech New Aragon entities

12.2.2 What is to be learnt?

The aim of examining the jet-trainer support operation is to understand:

- How a Solution is stood up and managed in a real-world setting
- Some of the nuances of running and managing a Complex Solution
- What role engineering plays in the delivery of a such a Complex Integrated Solution
- The challenges and behaviours the CIS approach may drive in the sustainment/in-service engineering function.

This case study covers seven separate chapters (plus one Appendix) and goes into much detail about the architecture, history, responsibilities, and challenges associated with the Complex Integrated Solution. In particular, this case study describes the following characteristics:

- The contract and safety requirements
- The Solution Delivery Group that was set up to deliver the Solution, including the organisational structure arrangements and essential functions used in the Solution's delivery
- The history and process of establishing the Solution, both the aircraft development activities, as well as the organisational and capability aspects
- A detailed examination of the Engineering Unit, including its interaction with the Type Design Group
- An examination of some of the challenges, developments, and opportunities for the future of the Solution.

[15] Both design and continuing airworthiness.

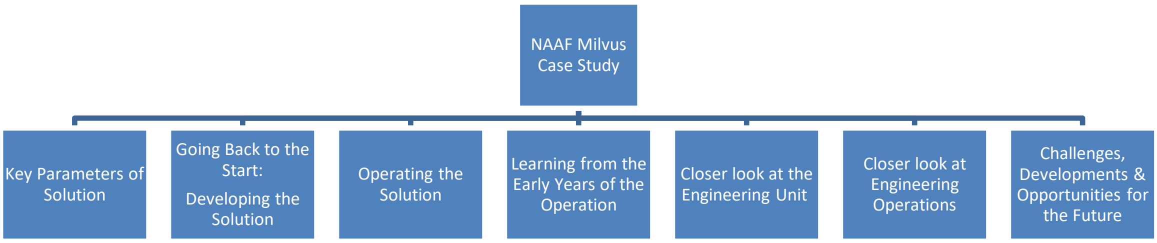

Figure 35: Structure of Case Study 1

12.3 Case study 2

Case study 2 examines the Engineering Group of EmeraldJet Airlines, the pseudonym of a leading low-cost airline carrier with a flamboyant brand image and customer-focused culture. At the point of the investigation, it operated a fleet of approximately 60 aircraft of two FAR25 jet-types. However, this case study doesn't merely describe the status quo of its fleet management operations.

Figure 36: Logo of the pseudonym airline carrier, EmeraldJet

12.3.1 A unique angle

This case was investigated at a unique point in the airline's life, with the company celebrating ten years of operations while going through a period of consolidation, reflection, and maturation after a busy decade of rapid growth.

As part of this inflection point in the airline's journey, the airline's executive management team were scrutinising how the Engineering Group was engaging with the broader company operation, and why it was not seen to be doing all it could to contribute to the airline's success. It also considers deliberations and actions on the part of a new Engineering Group Manager whose role was to reshape the Group as a principal operations enabler and not sideline support function. It's a case very much worth examining, as it offers a keen insight into the internal thinking of an airline whose deliberations also touch on the very role of engineering in the in-service environment, a topic at the very heart of this entire report.

12.3.2 Does it relate to Complex Integrated Solutions?

Does such an Engineering operation, merely a division of an airline company, constitute a Complex Integrated Solution? Surely Solutions are outsourced and contractual activities? This report puts forward that there are two reasons why this account can indeed be considered a Complex Integrated Solution.

First, Complex Integrated Solutions don't always have to be delivered by an outside organisation, especially given the notion of internal Service Level Agreements, or how PBL concepts are used within the US Military. Whilst in this instance, there is no formal contract between the Engineering Group and the rest of the airline (which does provide a slight limitation on a one-for-one comparison between case studies), there was a corporate expectation of performance on the Group that was still powerful. The Group still delivered a Complex Integrated Solution around fleet availability and provision, even if it wasn't called that.

Second, the case to be illustrated exhibits many characteristics of a Complex Integrated Solution. The level of embeddedness with the 'customer,' the capital assets involved, the make-or-break nature of the 'input' (aircraft availability and fleet provisioning), as well as the perceived independence of the Engineering Group from the rest of the airline means it represents conditions very similar to an outsourced Solution.

Third, there's likely to be value found in understanding how a prospective Solutions customer – i.e., an airline – might organise itself if, hypothetically, it was to become such a provider. How might it respond to meet the imperatives and requirements a Solutions customer may face? Given its experience as a 'customer,' it would be uniquely placed to understand these imperatives, and likely organise themselves well to respond. Thus, there are lessons that can be taken from this unique angle.

This case study does exhibit a key commonality with the first case study: it also primarily focuses on a provider delivering a Fleet Solution to an aviation operations client. Similar commercial pressures apply to the previous case study, and thus this case study permits a closer examination of what engineering in the in-service environment looks like, and what types of demands are made on engineering in this context, and how the Embedded Engineering Function might respond.

12.3.3 Case study approach

There are a few important limitations of this study that are worth identifying for the sake of completeness.

First, it does not examine the start-up of the airline nor of the Engineering Group, although it does touch on how the Group started moving towards becoming a Solution, rather than just a corporate division.

Secondly, this is not a review of the change management process, and thus does not go into any detail about how the change was deployed, nor of how the change was accepted and adopted by the Group. This case study does not even review whether the changes implemented were a complete success (in part due to the research design been more exploratory rather than longitudinal). Such considerations are the mainstay of research into change management; however, this study seeks to understand the drivers, perspectives and professional insights into why the original status quo of the Engineering Group did not meet ‘customer’ expectations.

Third, this case study is partly ‘digested’ before it is presented. Rather than a simple laying down of facts as observed, this case study is viewed through the lens of experience of the study’s author. To then make this case more useful to learn from, it has included efforts to ‘reframe’ or describe in more meticulous detail concepts that are normally accepted as professional jargon (such as ‘managing the configuration’). As such, the presented case study constitutes findings, rather than results.

Appreciating that these factors place some limits on what can be learned from the case study are important to appreciate better the context and nature of what is presented, and how it can be accurately used. Nonetheless, this case makes for essential reading to gain further insights into the role of engineering in the complex and dynamic in-service operations domain.

12.3.4 Case study structure

This case study is delivered over two chapters. The first chapter (Chapter 20) looks at the airline’s inner workings, how the Engineering Group is structured, and key responsibilities and functions of the Group. It’s set after major changes were introduced to the Group. The second chapter then focuses on the rationale and associated efforts to transformation the Engineering Group from a ‘traditional’ outfit, to a more sophisticated, service-driven outfit that’s aligned with the imperatives of the broader company.

The case study description and account is produced from two key sources of material: a workshop with Engineering Group managers, and from internal documentation. The workshop covered both briefings and descriptions of the various functions and units that made up the Group, as well as recounting the journey of the change process. Questions were asked particularly from the perspective of what attributes of the Group were important to reshape to become a more focused, higher-value technical service provider to the rest of the airline. Internal documentation, including copies of performance reports, the organisational structure, and internal process descriptions, helped solidify the case description.

12.4 Making sense of the case studies

Following the presentation of case study findings, this study then pauses in Chapter 22 and seeks to capture some of the key observations and lessons that can be garnered from the case study material. It’s these observations that form the basis of Parts IV and V as they seek to unpack and articulate some key insights and ideas about Complex Integrated Solutions, and the Embedded Engineering Function.

CHAPTER 13

A New Era for Fast-Jet Training

Case Study 1

13.0 A comprehensive Complex Integrated Solution

Imagine a highly experienced aircraft manufacturer breaking the traditional mould. Where instead of confining itself to designing and selling aircraft, it engaged in offering an Air Force operator a fast-jet training Solution so comprehensive that the customer engages in virtually no other aircraft sustainment or management activities, apart from 'kicking the tires and fuelling the aircraft' before a training sortie. This extensive case study, presented over the next seven chapters, is the story of an exemplary instance of such a Complex Integrated Solution provided to the New Aragon Air Force.

This chapter focuses in on:

- The key parameters of the Solution contract (customer expectations and requirements)
- An overview of the Solution operation
- The key players in the Solution.

13.0.1 A global operation

The CIS provided to the NAAF is an availability-driven, performance-based contract for a fleet of jet trainer aircraft where the provider must ensure there are 28 operational aircraft readied for role-specific operations every day. Non-attainment of this goal leads to substantial penalty payments that are deducted from the contractor's monthly fee.

The fast-jet training fleet is made up of a total of 33 turbofan-engined, two-seat, subsonic, advanced jet trainers called the *Milvus*, originally designed in the 1970s by *DefTech Global* in Essenheim. The aircraft used by the *New Aragon Air Force* (NAAF) are highly updated versions of the Milvus, and whilst the NAAF owns the fleet, they are managed and supported by DefTech Global's New Aragon Division (called *DefTech New Aragon*).

DefTech New Aragon holds the comprehensive in-service contract which is concentrated around two main customer venues, both being major Air Force bases – one on the East coast, the other on the West coast of New Aragon. The contract is seen by the customer organisation as a leading example of a change in contracting approach, moving away from a piece-meal work regime, to an integrated and comprehensive arrangement where the contractor undertakes all management of the aircraft. This frees up the operating customer unit to primarily focus on extensive flight and air combat training operations, rather than aircraft sustainment. It's been seen as a model arrangement for future contracts for other Defence assets, particularly with its focus on delivering operational capability as an ongoing service, rather than a one-off delivery of a product.

13.0.2 New Solution, traditional language

While this study views this scheme as a Complex Integrated Solution, technically speaking, the in-service contract does still utilise traditional contract management frameworks used by the New Aragon Defence Department. Namely, the aircraft is acquired via an acquisition contract, and the day-to-day service-solution is managed under an in-service support contract that still uses a traditional Statement of Work (SoW).

However, when the story of the whole scheme emerges, it clearly fits the characteristics of a Complex Integrated Solution:

- The support program is slated to last at least 25 years
- Expenditure per year is circa $100million
- The service provided is highly embedded in the customer's operations – indeed, the customer is entirely dependent on the contractor upholding their responsibility for the training fleet.

13.1 Solution genesis

13.1.1 An important contributor to national defence

As an advanced Airforce, the NAAF operates several Squadrons of highly sophisticated jet fighter/attack aircraft in the air-combat role. Such sophisticated weapon systems thus dictate an uninterrupted supply of highly proficient pilots and systems operators to utilise the full capabilities of the aircraft.

As such, the NAAF places a major emphasis on its front-line fighter training system and deems a fleet of fast-jet trainer aircraft as an essential part of that system. These aircraft are used to prepare future fighter pilots for the challenges involved in operating very-high-performance fighter aircraft and the advanced weapons they're armed with. As the NAAF take this training regime seriously, they do not believe that it is efficient or prudent for pilots to graduate from lower-performance-grade aircraft (such as single or twin-engined turboprop aircraft) onto the front-line aircraft without mastering a subsonic and 'safer' type of fast-jet aircraft. Hence, the fast-jet trainer fleet is a crucial contributor to the NAAF's mission.

13.1.2 Replacing airframes, buying capability

The NAAF's existing fleet of jet-fighter-trainer aircraft was slated to be withdrawn from service in late 2000 following some 36 years of service by the Type. Thus a project was launched by the New Aragon

Department of Defence in the mid-1990s to examine options for replacement and to place a contract with a winning bidder for a new fleet.

In 1997, a contract was awarded to DefTech Global for the construction and delivery of 33 aircraft based on a 1974 design called the *Milvus*. These aircraft, however, would be installed with newer systems, including digital flight displays, new generation oxygen generation systems, a new digital flight information architecture (including the weapons management system), and onboard Health and Usage Monitoring System (HUMS). Given the aircraft's integral role in the NAAF's frontline training program, the aircraft's systems emulate the advanced systems used specifically in their front-line fighter aircraft – even the display symbology and systems functionality of these fighter aircraft are emulated on the training aircraft.

Whilst the order that was placed was somewhat classical in its approach, the overall contracting strategy was unique for the New Aragon Department of Defence, and to a certain extent, for DefTech Global as well. There were three unique facets of the contracting approach.

13.1.2.1 An integrated approach

The first unique aspect was the intention to award a 25-year in-service support contract to the manufacturer, broken into five, five-year intervals. The NAAF and Defence Department was keen to more than acquire an aircraft type, but rather wanted a comprehensive maintenance and support scheme that would remove the technical burden on the NAAF for the upkeep of the fleet, and instead shift the majority of their Squadron's attention to extracting the maximum flying training benefit from the fleet.

The use of renewals every five years also permitted the contracting arm of the Department of Defence to monitor and influence contractor performance over the long-term. Should there be issues and concerns about the long-term effectiveness of the contractor, these "off-ramps" would give the Government scope to find alternate arrangements. However, such arrangements also provided the contractor, as well as the customer, scope to renegotiate aspects of the 5-year support deals to account for changes and adaptions to the Solution as time progressed.

13.1.2.2 Hours, not airframes

The second unique aspect of the contract was that the Request for Proposal (RFP) issued to industry did not stipulate the number of aircraft to be purchased. Rather, it asked for a proposal that would facilitate 9000 flying hours of flying training annually.

Industry respondents were required to determine what the most cost-effective mix of aircraft, synthetic training devices (simulators) and maintenance activity would be to meet this 9000 flight-hour training concept of operations. This would, in turn, drive the bidder's proposed Solution of both aircraft and simulator development and acquisition, as well as the support services (hence the 25-year approach to cover the anticipated life-of-type) to carry out the industry component of the training concept Solution. In effect, this placed the training Solution design analysis onto industry.

During the bid phase, DefTech Global determined that to achieve this goal, a total of 33 aircraft would be required, with 5 undergoing deeper maintenance at any one time, with the aim of delivering 28 airframes for use daily. Chosen as the winning contractor, the acquisition contract ultimately specified the 33 aircraft based on the analysis by DefTech Global.

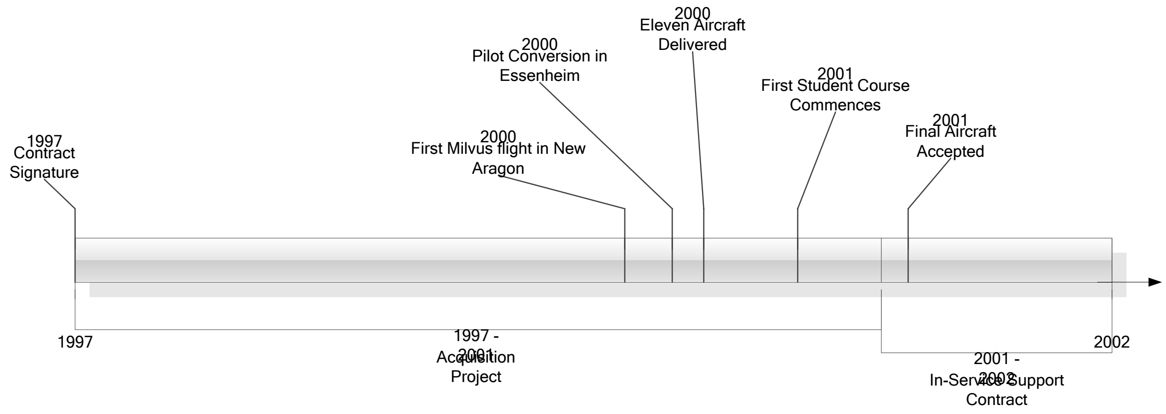

Figure 37: History of the development of the Complex Integrated Solution

13.1.2.3 Building presence

A third unique aspect of the deal was involvement of local industry in the construction of the aircraft, although not strictly an approach unique to this contract, given the New Aragon Defence Department already had a local industry participation policy. However, how this policy was enacted was innovative and was ultimately used by DefTech in a compelling way to both win the contract and establish their presence in the delivery of the Solution.

Of the 33 aircraft delivered, 21 were assembled at DefTech New Aragon's facility located at the same airfield that one of the two training Squadrons (operator-customers) is based at. This airfield is home to a number of Units and Squadrons and has been referred to as a 'super-base' because of the diversity of activity.

The facility is located on-site, but on the opposite side of the main runway in a commercial precinct. The facility was constructed after the contract was awarded and was used in the assembly of the 21 aircraft (the first 12 aircraft were built at the company's Essenheim manufacturing site and ferried to New Aragon). The facility was built to be multi-purpose – initially for aircraft production, but soon became the main venue of aircraft maintenance for the Squadron located at this airfield. The contractor leased a venue from the NAAF at the other airbase.

By building a facility larger than was necessary for the training Solution, DefTech New Aragon built itself a strong presence at the customer's Airforce Base and was able to win other maintenance contract work shortly after. An additional benefit from assembling aircraft in-country was the construction work was done by staff that became the maintenance staff on the aircraft following the awarding of the in-service support contract. This experience has been identified as having been a very useful source of knowledge when supporting the aircraft.

13.1.3 Smart buying

In the final acquisition contract, the New Aragon Defence Department went beyond the normal specification of the flyable aircraft to be purchased and detailed many other items to be procured to enable a highly versatile and resilient Solution scheme.

The contract covered the delivery of ground-based training aids, including a simulator, and included the usual assortment of technical publications, Ground Support Equipment (GSE), and spare parts. The contract also called for some unique deliverables:

- the specification for one of the 33 aircraft to be specially equipped to carry out a part-time flight-test role (rigged complete with orange-coloured test system wiring)
- the purchase and delivery of an additional airframe (structure only) with a qualified test rig and equipment.

The additional airframe and test rig were intended as a full-scale fatigue test setup to validate the actual life of the airframe construction and evaluate any potential for life extensions; the aircraft rigged for flight test was to permit in-service tests of new equipment, new tactics and permit localised trouble-shooting.

Such initiatives were part of a customer desire to not only own a reliable and highly-available aircraft fleet but also to own the capability of expanding the envelope throughout the aircraft's life. Given the NAAF seek to continually have the edge in front-line air combat tactics, techniques and procedures (TTPs), the need to have an adaptable training system to train pilots for new concepts is an important part of the Solution scheme.

One other customer expectation – albeit not strictly an acquisition requirement – was minimum levels of local industry involvement in the in-service phase of the program. Such a strategy is part of the New Aragon Defence Department's strategy for developing local industry, and thus constituted one of the 'start-up' tasks of selecting and approving local suppliers of support services.

13.2 Key stakeholders in the Integrated Solution

13.2.1 The customer enterprise

The complexity of aircraft operations, particularly in a defence environment, means the term *customer* is vague as there exists a complex departmental structure with different organisations providing differing functions as part of a broader enterprise that is known as *Defence*. In this case study, three main organisations are immediately concerned with the contract for an integrated solution: the contract-management organisation, the operating organisation, and the regulator organisation.

13.2.1.1 Defence Contract Management Agency

The DCMA, the contract-management organisation, is responsible for the managing of acquisition and sustainment contracts, including project management, contract variations and negotiations, reporting on contractor performance, and organising payment of contracts. The specific administration of this contract is undertaken at a unit level of a Capability Program Office (CPO) – itself a unit of a larger division within the overall contract management organisation. In this case, the overall organisation employs over 7000 staff, but for this contract, 6 staff are dedicated on a full-time basis. This is considered quite small when compared with other support contracts of a similar nature. This is because of the comprehensive nature of the sustainment contract where virtually all activities are integrated and coordinated by the contractor, requiring little coordination from this unit.

13.2.1.2 Operator-customer

The operational Squadrons are in effect the end-users of the Solution. They're the operational coalface, where the solution's value is realised. In this case, they are the actual organisation that operates the aircraft, piloted by crews that have been trained on the training devices (such as simulators) that have also been supplied under the contract.

They also take on responsibility for what is termed Operational Maintenance (OM). Closely aligned to the term Line Maintenance in the civil world, OM involves such things as checking serviceability of aircraft before launch, making very minor repairs (such as changing out line-replaceable units), and providing technical support to operating crews before aircraft departure (such as assistance when strapping in pilots). Operational squadrons are extensively involved in the management of the airworthiness of aircraft and drive the availability requirements on a daily basis. However, they do not have much oversight with contractual matters – this is done in conjunction with the contract management organisation. These Squadrons themselves are relatively small sections when compared with the rest of the NAAF.

13.2.1.3 Customer-regulator

The Defence Aviation Safety Regulator (DASR), an independent unit within the NAAF organisation, is responsible for setting and enforcing technical airworthiness standards across Defence aviation units. The established regulatory regime also covers contractors who are engaged by the contract-management organisation for undertaking any work on aircraft or aviation product on behalf of Defence. This regulatory framework includes design certification standards, system-safety program requirements, and approvals for maintenance operations and engineering support services.

13.2.1.4 Conflicting imperatives

Each of these key customer divisions has their own requirements and interests which potentially causes conflict when devising, executing and managing a project to establish a Solution. The DCMA is primarily concerned with cost, schedule, and adherence to the system specification as laid out at contract signature. The operational units are concerned with the day-to-day business of flying operations and are concerned with aircraft availability, safety, and running operations as smoothly as possible – in this instance, retiring one fleet and introducing another became an additional burden which impinged on their core business of flying and training. The regulator organisation, naturally, has another set of interests, namely strict compliance with regulations to ensure a level of technical airworthiness and safety of a new product that is being introduced, as well as operated and maintained.

Ultimately, there is also the political-customer – the entity that 'owns' the entire defence organisation, namely the Government and the people who elected that government. With a spate of high-profile defence project blow-outs – financial and schedule-based – there is a continual political scrutiny on the performance of sustainment programs and acquisitions. In recent times also, there has been a strong emphasis on cost-reduction and reform throughout the entire Defence Organisation, including on existing contracts where contractors are being asked to find ways of reducing costs.

13.2.2 The contractor enterprise

The business unit that delivers the Solution will be referred to as the Solution Delivery Group (SDG). However, it's but one small part of the much larger DefTech Global enterprise which has at its core a servitization strategy. As a global defence contractor based in Esssenheim, DefTech Global has business activities in several countries on most continents. Their product portfolio includes fighter, trainer and reconnaissance aircraft, submarines, combat ships, ground-based vehicles and weapons, as well as munitions, and electronic systems. The servitization drive within the company is in alignment with Essenheim's official industrial policy for defence that seeks to establish an industrial base that is not reliant on designing and building brand-new systems, but rather is strong on systems and in-service management of existing assets.

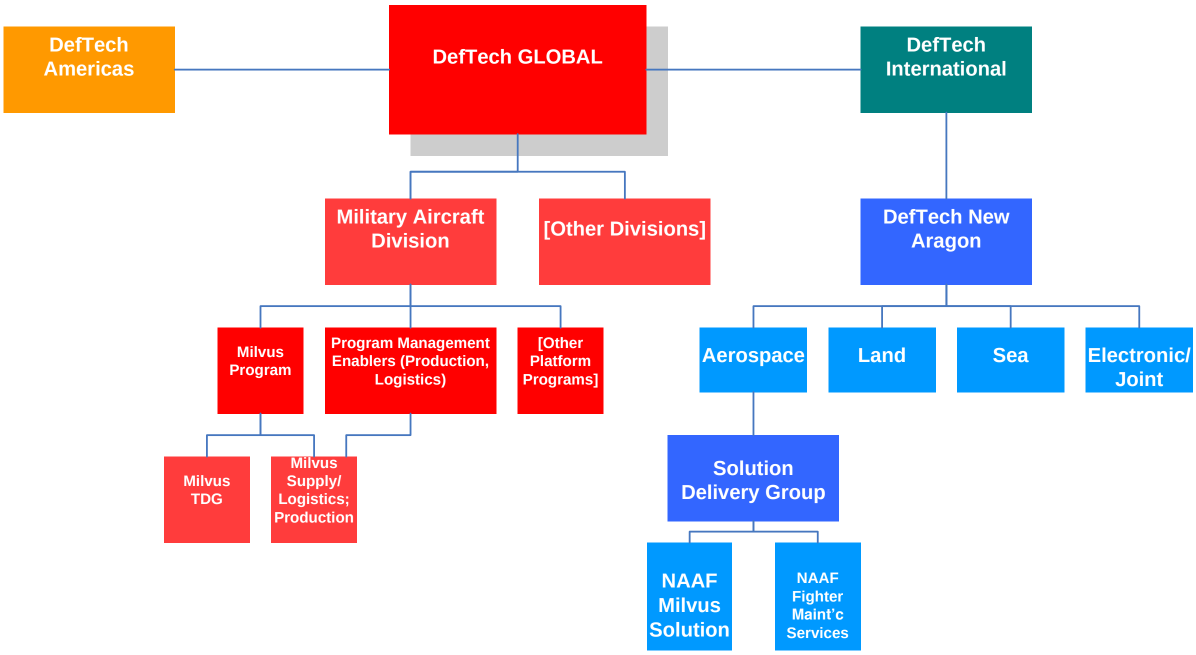

Figure 38: DefTech Global organisation (focusing on units relevant to the Milvus program)

The company is organised into three major divisions – DefTech Global (based in Essenheim, and the core of the enterprise), DefTech International which is the division which owns and operates DefTech New Aragon. It's a little confusing, particularly since the two key contracts for the Solution – acquisition and sustainment – were placed with two separate parts of the DefTech enterprise:

- The acquisition contract for the delivery of the aircraft and associated components and systems was placed with DefTech Global with their Military Aircraft Division, where manufacturing of the aircraft is performed (the aircraft was originally developed for the Essenheim Air Force, and the management of the Type Design is carried out at the production site).

- The in-service support contract, however, is placed with the aerospace division of DefTech New Aragon.

13.2.3 The Solution Delivery Group

The Solution Delivery Group, a business unit within the Aerospace Division of DefTech New Aragon hosts the ongoing management of the Solution for the Milvus.

It is one of two programs run by the business unit, the other a large maintenance contract for another aircraft type for the same customer air force and project management group (although the operating units are different). This other maintenance contract is a more traditional transactional-style contract based on the amount of effort (i.e., work hours performed) by the contractor, and only covers actual “hands-on-spanners” work. The control of the aircraft configuration, including such things as modifications, repair scheme development, and decisions on unserviceability’s – all engineering functions – still rest with the customer project management group and its own engineering teams. The structure of the SDG is given in Figure 39.

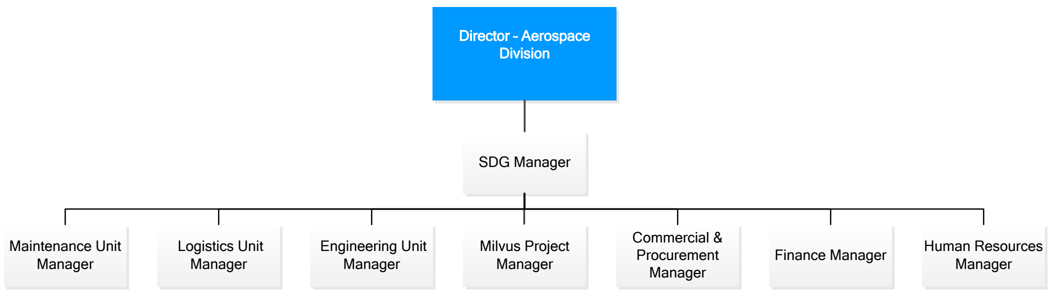

Figure 39: The Solution Delivery Group, one of the units of the Aerospace Division of DefTech New Aragon

13.2.3.1 Regulatory requirements

The makeup of the SDG had to consider several constraints and requirements, particularly aviation regulatory specifications, and project management constraints. To deliver an Integrated Solution, the SDG must apply, receive, and continually hold numerous authorisations from the DASR. These include Certified Engineering Organisation (CEO) and a Certified Maintenance Organisation (CMO) status.

Such Certifications grant certain privileges to undertake engineering and maintenance activities respectively. Each certification pertains to a recognisable work-team structure of groups residing within the SDG that clearly define the boundaries of a certain activity (namely engineering or maintenance), and are intended to define key lines of authority and responsibility unambiguously. To achieve this, the processes and procedures that must be followed for specific activities and decision-making are documented in a management system that controls the function of each group. This disciplined approach is a way of controlling safety-critical operations, as well as providing a means of independent oversight by the regulator through audit and surveillance activities through traceability the approved management system provides.

13.2.3.2 SDG Scope

Whilst numbers fluctuate, the workforce strength of the SDG is around the 300 mark, including maintenance, engineering, logistics, administration and project management staff.

The SDG is headquartered at one of the NAAF's main bases, adjacent to Squadron's own facilities which also house the main office of the customer contract management organisational unit that is responsible for the contract. The majority of the Solution activities are also located at the SDG's headquarters, including the Engineering Uni, most of the logistics unit, and about two-thirds of the maintenance unit. The other major venue for operations is located more than 1000km away on the other side of the country where another Squadron operates a smaller number of the Milvus. A maintenance facility is leased from the Squadron and is staffed and managed by the SDG, providing the same function as the facilities at the SDG headquarters.

Whilst the localised team structure is necessary to consider, it is not the entirety of the structure of the Solution. There exists a more complex relationship with other suppliers, other units (including the Type Design Group) within DefTech Global, and with other customer organisations (such as the customer's Science & Technology arm). The Integrated Solution cannot be adequately understood until these other relationships are considered.

13.3 Key contract, performance & service requirements that defines the Solution

13.3.1 Contracted Performance Deliverables

The headline deliverable for the solution is aircraft availability. However, there are some additional responsibilities and associated performance metrics which are to be met by the SDG. The contract is performance-based, and payments are made based on the attainment of certain performance metrics. Failure to achieve given targets, depending on the circumstances, can trigger liquidated damages (LD's), restitution to the customer – either through financial penalty payments, or providing 'free' work or services in-kind.

There are five key performance-based deliverables:

1. Daily aircraft pool availability
2. Repairable Item (RI) Demand Satisfaction Rate (DSR)
3. Consumables and Expendables (C&E) DSR
4. Training Aid Availability
5. Mean Time Between Critical Failures.

13.3.1.1 Aircraft availability

The primary deliverable is the provision of a daily pool of 28 operational aircraft ready for flying, shared between the two operational venues. For each aircraft not delivered below this level, a per-aircraft penalty applies.

13.3.1.2 Demand satisfaction rates

Repairable Items are equipment and components that are removable from the aircraft, and can be maintained, repaired and overhauled off-aircraft (and even off-site) – for example, pumps, avionics equipment, and sensors. Many of these items are line-replaceable Units (LRUs) – i.e., customer maintenance crews would be able to replace these units at the operating base, in some cases just before flight. Under the contract, spares and RIs are managed by the SDG and are held on their premises. Whenever an LRU is required, the operator-customer places an order with an associated priority – anything from a five day turnaround, through to delivery required in one hour from placing the order. The Demand Satisfaction Rate represents the achievement of the provision of the RI according to its priority rating. Under the contract, there is a minimum percentage that must be attained before any form of LDs is enacted. The management of these repairable components is one of the functions of the logistics unit within the SDG.

A similar principle applies to the provision of Consumables and Expendables. These items, however, are non-repairable and are often such items as oils, filters, bearings and other non-repairable items (i.e., discard after useful/approved life). The same demand satisfaction regime of RIs is used for C&E.

13.3.1.3 Training aid availability

The availability of training aids is the fourth measure of solution performance. The training system aspect of the solution is comprised of computer-based training consoles, both for maintenance and flying crews, and actual flight simulator units at both operator bases. The SDG is responsible for ensuring that these systems are online and available for use for at least a given percentage of time.

13.3.1.4 Critical failures performance

The last performance measure relates to the aircraft's technical performance in the air. It is a targeted minimum amount of time between in-air failures that would cause that particular flight's mission to be aborted. It is not a measure of all system failures, as there are several systems with redundancies that would not require an immediate suspension of flight and return to base. However, any failure that would cause a loss of a mission (e.g., a mission system or a safety-critical system) would be recorded. The delivery of this performance is measured in flight hours between events.

13.3.2 Not all metrics are created equal

When the second phase of the in-service support contract was signed, a fundamental change was made to these metrics that saw the contract management and operator customer define weighted performance priorities. Major weighting is placed on the daily available pool of aircraft, but modest weightings are placed on the other four areas. 'Staggered' LD's were also introduced, dividing performance that was below-target into different levels to differentiate between occasional underperformance through to consistently poor performance, with a penalty weighting appropriate to each level. This sliding scale reflects a more considered approach to enforcing penalties on the SDG.

13.3.3 In-service work scope & Solution deliverables

Whilst the performance-based contract is outcomes driven, thus providing more freedom to the contractor to deliver as it saw fit, the contract still stipulated various activities so the customer could control various aspects of the Solution. Safety, quality and financial perspectives were key areas that came in for some level of a standardised and mandated approach. Thus, the contract required that the SDG establish the following functions:

1. **Deeper Maintenance:** The provision of inspection, servicing, repairs and overhaul of aircraft in the fleet
2. **Weapon System Logistics Management (Engineering Management):** Management of the fleet to ensure its continued airworthiness and ongoing fit-for-purpose status
3. **Logistics Supply Management:** The timely supply and management of spare parts and other mission items
4. **Warranty management:** Replacement of defective product
5. **Survey & Quote:** Quotation services for activities beyond the scope of the contract
6. **Lifecycle Cost modelling:** Collection, modelling and analysis of cost data associated with the provision of the integrated solution
7. **Mechanism for sharing cost-savings:** Initiating a process for the joint-sharing of efficiency gains between contractor and customer.

The Deeper Maintenance, Weapon System Logistics Management (Engineering Management), and Logistics Supply Management functions are described in detail in subsequent Chapters. For completeness, however, the remaining four areas are described in this section as they place the requirements of the integrated solution into perspective.

13.3.3.1 Warranty management

Of interest for this contract is the warranty management activity. One of the key foundations of the contract is that all costs associated with the maintenance, upkeep and continued safe operation of the aircraft fleet are to be borne by the SDG, except for items considered out of contract (this is carried out under the Survey and Quote function). Under traditional contracts, each activity would be charged to the customer on a work-hour basis, plus the price of components used, and any non-conformance, under-performance or failure of components would be managed under a warranty claim process. Under this contract, however, payments to the SDG are predicated on the availability of the aircraft, not dissimilar to the hiring of an asset. As such, when preparing a bid for the contract, the SDG needed to estimate the total costs associated with the upkeep of the aircraft and consider any potential variations and abnormal circumstances that would affect the overall cost to be incurred over the life of the contract. This includes costs associated with maintenance, spares and consumables, costs associated with mandated airworthiness actions such as inspections, modifications and rectification of design flaws, and other cost-inducing factors. It also means that any item or component not performing as required needs to be repaired or replaced – effectively a de facto warranty arrangement. A price, including risk buffers and margin, would then be based on these deliberations.

Despite the theoretical simplicity and seamlessness of this de facto concept, in practise there still exists a warranty function to manage this requirement. Some specific performance parameters are called up in the contract, rather than blanket coverage. The agreement requires that the SDG warrant and guarantee:

- A structural fatigue life of 10000 hours per airframe (if modifications to the aircraft are needed to reach this target, costs are to be met by the SDG).
- The rectification of latent defects in the supplied aircraft at the SDG's expense for the 25-year life-of-type
- A 24 month (from customer acceptance) coverage of supplied spares (customer-owned pool) on defects and deficiencies of design, performance, materials and/or workmanship
- Availability of the engine fleet to provide 225,000 hours of operation over the life-of-type
- A filling of any shortfall of LRUs as required to support the aircraft at no additional cost.

The SDG has its own internal warranty function for 'pass back' to suppliers through the Logistics Unit.

13.3.3.2 Survey & quote

There are some activities and work associated with the Solution and the associated management of the aircraft type that are not covered under the primary support contract. Instances of these vary but tend to include abnormal damage to the aircraft during operations (an issue of insurance, not warranty), enhancements to the capability of the aircraft, through to the proactive adoption of new technologies or systems to improve safety. Products and services relating to these out-of-scope items are processed using a survey and quote approach whereby the SDG will examine the work to be undertaken and subsequently issue a quote for the estimated completion of the work. If accepted, a separate contract is then issued for the work-package to be performed.

These activities can be random and unexpected and vary in scope. For example, one of the trainer aircraft was involved in a mid-air incident where one wing was extensively damaged after hitting high-voltage power lines. The aircraft was subsequently grounded whilst a repair scheme was devised. Another example involves the installation of a new radar emulation system – a retrofittable system that simulates the presence of other aircraft (friendly and hostile) on a cockpit display using data transmitted from other aircraft or ground stations. As this system does not require an actual radar device, this addition boosted the training realism features of the aircraft at a lower cost.

13.3.3.3 Cost-saving sharing management

With one of the main objectives of the performance-based philosophy to reduce costs, the contract stipulates a cost-savings sharing scheme between the SDG and the customer. Costs of the Solution are reviewed on a periodic basis, and a pre-agreed proportion of any savings are handed back to the customer. It is a process that is managed by the SDG, and not the contract management organisation, although they're granted access to the financial records.

13.4 A much bigger story

Whilst this chapter has provided a basic overview of the Milvus Integrated Solution, it's a story that needs significant levels of unpacking. Just how did the Solution actually come to be? How is it operated on a daily basis? What exactly does the Engineering Unit do? What are some lessons to be learnt from some of the developments and changes made 'inflight' with this Solution? These are questions that are unpacked over the next six chapters.

CHAPTER 14

Going back to the Beginning

Case Study 1

14.0 A history of the Milvus Solution

The key narrative of this Complex Integrated Solution is aircraft availability – it's the headline metric and perhaps what the Solution is most renowned for. Yet, the Solution's history is more complicated than one performance measure.

This Solution is not merely the redevelopment of an existing aircraft design; rather it is a multifaceted concept that to be properly understood, must be explored from its origins. As such, this chapter seeks to explore questions such as:

- Where did the Solution have its genesis?
- What were the critical steps in bringing the Solution 'online'?
- What were some of the imperatives and challenges faced while establishing the Solution?
- What have been some of the persistent core needs of the customer that the Solution responds to?

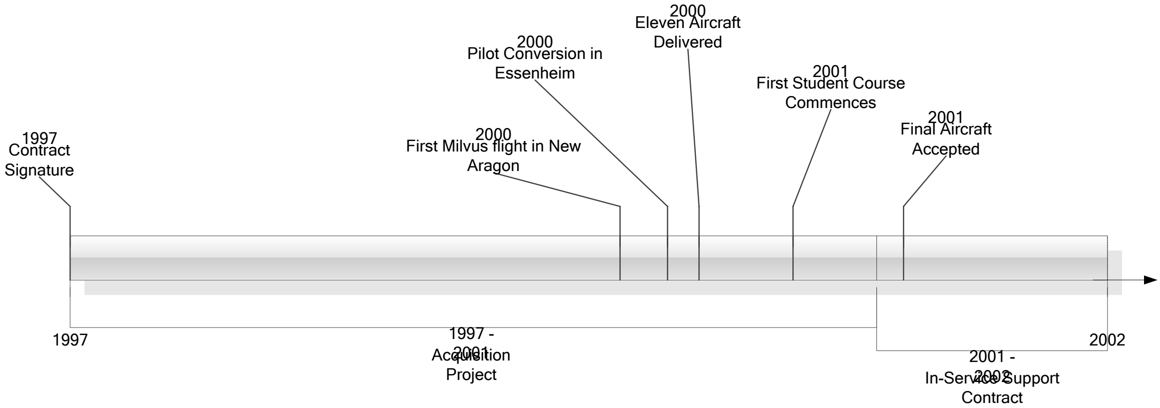

Figure 40: History of the development of the Complex Integrated Solution

This snapshot is broken up into key phases in establishing the Solution:

- bidding for the contract
- negotiating the details of the solution
- coordinating and planning the execution of the Solution
- establishing the Solution Delivery Group
- supporting the customer organisation in the ramp-up and transition to the Solution
- the delivery and Entry-into-Service phase of the fleet, and
- the subsequent 'go-live' of the in-service aspect of the Solution.

The Solution's history is just as important to consider as the current day-to-day business because it sets the foundations and fundamentals. This is the account of the Solution's development and formation to becoming a 'steady-state' operation.

14.1 Designing a Solution, and bidding for the contract

When the prospect of a new, innovative competition to sell advanced jet fighter trainer aircraft emerged in the 1990s, DefTech Global mobilised several facets of the Company to respond and submit a bid.

However, a particular emphasis was on personnel within the Type Design Group who held key 'new business' responsibilities. The TDG became involved in coordinating many of the technical aspects of the Company's offer, particularly since the initial contract was for the acquisition of aircraft (the Company also had to bid on the in-service support contract as a separate legal contract, despite the significant overlap in activities and value-proposition).

As the Request for Tender specified a fleet make-up capable of achieving a fleet-wide effort of 9000 flying hours per year, the Company's pre-bid activities focused on:

- Synthesising possible configurations of the Solution, including the number of aircraft, arrangements for the support of the aircraft (such as spares, provision of maintenance, and key infrastructure), and other product-based offerings that were required to meet the specified need
- Gathering data and modelling these potential offerings to put estimated costs around each proposal and to determine pricing of the offer
- Testing and analysing each of these potential offers for a viable business case that would also put the company in a winnable, but also profitable, position
- The evaluation, refinement, narrowing down, and eventual selection of the principal offer that the company would provide to the customer.

The bid team finally put together a proposal that specified much of what became the final Solution. This included pricing for the delivery all major deliverables as part of the acquisition contract in preparation for been awarded an in-service contract for the fleet. The proposal included:

- A total fleet size of 33 aircraft, with a 28 aircraft required to meet the 9000 flying hours target

- A ground-based training system, including computerised aids and flight simulators
- The creation of a contractor support facility adjacent to customer-operator facilities, co-located on the same base
- The lease off the customer of another small facility at a west-coast base for the Squadron based there
- Establishment of the Solution Delivery Group, including logistics and engineering management
- Partnering with a local aircraft maintenance services firm to provide the staffing for maintenance work
- The delivery and management of the Full-Scale Fatigue Test setup.

The issuing of the RFT kicked off what became a three-way contest between three aerospace manufacturers, one of which was an updated version of the incumbent aircraft type already in use with the customer-operator. Following evaluation of the submitted bids, the DCMA recommended the selection of the proposal from this studied company.

14.1.1 Getting to the finer details

Despite winning the down-select process, there was still a period of negotiations that were held between the customer organisation (especially the DCMA) and the company, particularly in how the contract would be managed and delivered. One of these negotiation areas was a partnering approach between the DCMA, the NAAF, the operational Squadrons, and the company. This approach would ensure the primary stakeholders were involved in any decisions or amendments affecting the contract deliverables.

Another key negotiated approach to delivering the required capabilities of the aircraft was to use a staggered level of capability approach. Instead of using a ‘big bang’ approach to the incorporation of new systems and technologies onto an ageing platform design, more readily retrofittable technologies would be installed at agreed stages in the aircraft’s life.

The customer devised a Capability Realisation Plan to reflect this approach. Capability Level 1 would be the initial, certified baseline aircraft, itself capable of fast-jet training with a limited number of approved stores (i.e., payload of weapons carried on-wing). Capability Level 2 involved a software upgrade to enable the aircraft to carry and deliver an air-to-ground munition that is carried as a key weapon of choice by the customer-operator. The final Capability Level was the embodiment of a radar emulation and simulation system.

Level 1 was the initial delivery standard, with Level 2 completed shortly after the final aircraft was delivered to the customer organisation. This approach was particularly important as a later-than-expected signing of the contract covering the entire solution, without a change to the agreed delivery and ‘go-live’ date, meant that time to undertake the development, design, testing and other engineering work for the incorporation of these systems into the aircraft type was under greater pressure.

14.1.2 A new business model, a traditional management approach

It’s important to turn aside for a moment and review DefTech’s internal processes for responding to such an RFT. Even from the very outset, there was a potentially incongruent approach to pursuing, winning and executing a very customised and service-driven business opportunity. The the core of

DefTech Global's business management framework is a traditional systems lifecycle management approach. It's an approach that also guides business development and contract management efforts.

As it forms a central part of the company's internal policy, it cannot be reproduced here; suffice to say, it can roughly be broken down into:

- Pre-bid activities (preparation, review, and approval)
- Submission of bid & negotiations
- Reviewing system requirements
- Design & development
- Testing & system review
- Manufacture
- Delivery
- In-service support
- Close-out/retirement of system.

Whilst heavily system focused, it's still used across every business unit of the Company for all contract bids and execution management. Projects and programs across the Company's global operations are audited against this framework and forms the basis of a system of internal reviews and project governance. It's this framework that would 'guide' many facets of the Solution's development – especially the technical aspects. However, as will be seen, the Complex Integrated Solution depends on much more than quality hardware and systems.

14.2 Planning & coordinating the implementation of the Solution

Following the awarding of the Solution contract, the company had to begin planning and coordinating the various tasks to achieve a timely delivery of aircraft starting in 2000. On-time delivery was critical, as delays would enact penalty clauses in the contract, costing the company significant amounts of money.

Implementing the solution wasn't just a matter of making the necessary design changes to the aircraft, building it and delivering it – the fact twenty-one of the airframes were to be assembled in-country close to the customer's operations itself added extra complexity (discussed shortly). However, a number of non-aircraft aspects of the solution also needed careful attention and leadership. They included establishing the Solution Delivery Group that delivers and integrates all the components that make the Solution work, working with the customer organisation in readying them for the arrival of a new aircraft type, and aligning all the partners involved in making the solution a reality.

Most of these activities happened concurrently. To coordinate all this activity, a project manager was appointed. This manager, who worked within the Type Design Group in Essenheim, eventually moved to New Aragon to take up management of the Solution in the transition from acquisition to in-service support and remained with the SDG for quite some time.

14.3 Developing the aircraft design

14.3.1 Customer-driven redevelopment

While the baseline platform was an 'off-the-shelf' design, the customer organisation had formed a view that it had wanted several improvements over earlier models of the type.

During one workshop, one engineering manager explained how it was at the insistence of the customer organisation that the company considered sweeping changes to the existing aircraft model and thereby releasing a new model with numerous enhancements. Before the formal bid phase, the company had engaged with the NAAF and had initially offered the current generation model of the Milvus – a model which hadn't been updated since in the 1980s. With several new technologies available, plus a desire by the NAAF and New Aragon Defence Department for a trainer aircraft that met its specific needs, DefTech Global was encouraged to consider a re-design.

As such, a new version of the Milvus was offered and represented was a vastly different aircraft in terms of interfaces and systems. So much was the change that the company now touts this new model as the first of its "fourth generation"[16] family of fighter trainers, with another three models since released with other enhancements, ones which might form part of a mid-life upgrade on for this customer fleet.

14.3.2 An aircraft tailored to operator needs

Whilst the basic planform and shape of the aircraft remained unchanged, much of the internals were substantially redesigned, including:

- **Electrical Power:** Whereas older designs of the aircraft used a lower capacity electrical system, this new design used a greater power capacity network, required because of a higher electrical load by an increased number of computers and associated systems installed on the aircraft. This power system is supplanted by a newer APU that generates power at a higher kVA level than previous models.
- **HUMS:** The integration of a health and usage monitoring system was a key change. This system uses structural sensors around the aircraft to determine the real in-service loads that are exerted on the aircraft on each flight, helping to create a picture of the structural health of the aircraft.
- **Refuelling:** An attachable air-to-air refuelling kit was incorporated as standard (it can be demounted in a matter of hours if the mission requires it).
- **Oxygen System:** The redesigned aircraft included an on-board system to generate oxygen for use by the flight crew, rather than rely on oxygen bottles.
- **Wet-Hardpoints:** The aircraft was designed and certified to carry a variety of weapons that are carried on seven 'hardpoints' – attachments on the wing for holding and deploying payloads. Some of these hardpoints were re-designed as 'wet,' meaning they can be used for the carriage of fuel tanks to extend the aircraft's range.

[16] Much has been discussed about the various generations of fighter aircraft, with aircraft such as the F35 and F22 said to be "fifth generation" aircraft. The NAAF currently operates what is classed a fourth-generation fighter aircraft. It's this pedigree from which the Milvus is said to be a fourth generation aircraft.

- **Defensive Aids:** The aircraft was designed to be fitted with a range of defensive aids, including chaff to protect the aircraft against hostile missile threats.
- **Cockpit and Mission Systems:** To ensure modern weapons could be carried, the new Milvus model was decked out with new mission computers, as well as a dedicated stores management system which controls the release or firing of a weapon off the aircraft. In the cockpit, three new multi-function displays (MFD) present flight, weapons and sensor systems (including radar simulation) data to aid the pilot in conducting missions. An HOTAS (Hands On Throttle And Stick) arrangement was also installed, meaning that most mission-related functions, such as weapons selection and firing, can be performed without the pilot needing to take their hands of the critical flight controls.
- **Databus:** To support these integrated systems, a new digital databus network forms the backbone connecting communications, monitoring systems, sensors, computers, displays and stores management. Additionally, this revised model includes GPS navigation for the first time for the type.

14.3.3 Customer oversight

Designing, integrating, testing and certifying these changes to the existing type design was no small feat. To control this complex development program, the DCMA stipulated that a formalised systems engineering approach would be required to manage the engineering work. This included the documentation of requirements, the tracing of these requirements into a specification, the management of the design process to adhere the product to the specification, followed by a full qualification and testing regime. To oversee the development and manufacturing program, the DCMA established an acquisition team made up of elements of the customer organisation, including the operator organisation, and was co-located with the Type Design Group and associated production organisation.

14.4 Developing the safety case

14.4.1 Preparing for certification by the customer

The DASR has a strict and comprehensive regulatory framework that governs the technical airworthiness of its aircraft. This framework covers:

- Design standards required for the aircraft that it purchases (even if developed overseas)
- Processes for gaining certification before an aircraft is released for service (for both a Type and an individual aircraft)
- The process of managing the aircraft whilst in-service, including maintenance and engineering support
- The requirements for the development and improvement of the maintenance policy for its aircraft.

If DefTech Global had failed to attain design certification in time, it would have had a knock-on effect, triggering delay penalties. As such, the company constructed a comprehensive approach to developing the Safety Case for the aircraft – the structured, logical, evidence-based ‘argument’ that the aircraft is a safe product to operate under given certain conditions. The Safety Case is the product of a Systems

Safety Program (SSP) – a process that confirms the safety characteristics of the aircraft. It's more than mere 'box-ticking,' but an identification of hazards that could affect the aircraft, and a deliberate approach to mitigating those hazards.

14.4.2 Organising for safety

To deliver the SSP, the Type Design Group established a Project Safety Committee for the aircraft redevelopment project, which oversaw the SSP. It was responsible for making decisions regarding the specification of safety requirements and acceptance or approval of their implementation, including the publication of the Safety Case. The committee was composed of several parties including:

- representatives from the customer-organisation;
- aspects of the company's governance structure for airworthiness, production, training, configuration management, technical publications; and,
- the engineering development team itself (the Integrated Product Development or IPD team) that was designing the enhancements for the aircraft.

Embedded in the IPD team in the Weapon Systems Integration function was a Project Safety Engineer who was responsible for coordinating the activities required to meet the SSP requirements, including liaising with engineering teams, ensuring that they were following the required safety processes.

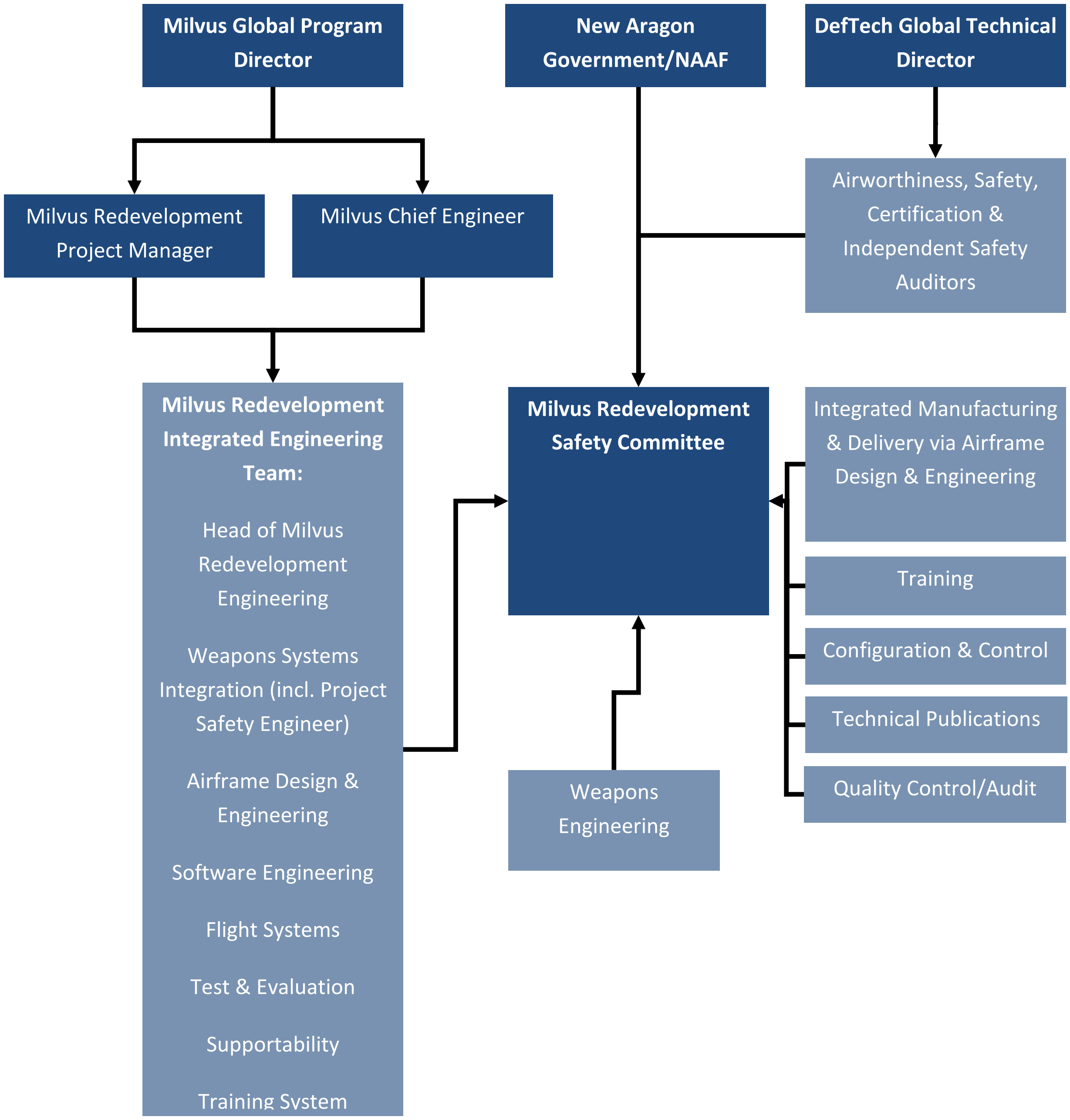

Figure 41: Aircraft redesign project safety organisation [adapted from company documentation]

14.4.3 Safety case development process

The primary SSP process used in Milvus redevelopment program is shown in Figure 42. It details how, through the product development lifecycle (or in this instance, the product re-development cycle), the engineering teams kept a close eye on potential hazards that could place the aircraft in jeopardy if not addressed. Hazards were identified and recorded in several mediums, including:

- through a formal and centralised hazard log or tracking database,
- at the Project Safety Committee, or
- in System Safety Working Groups (SSWGs) which were tasked with focusing on specific identified hazards and working them through to a solution.

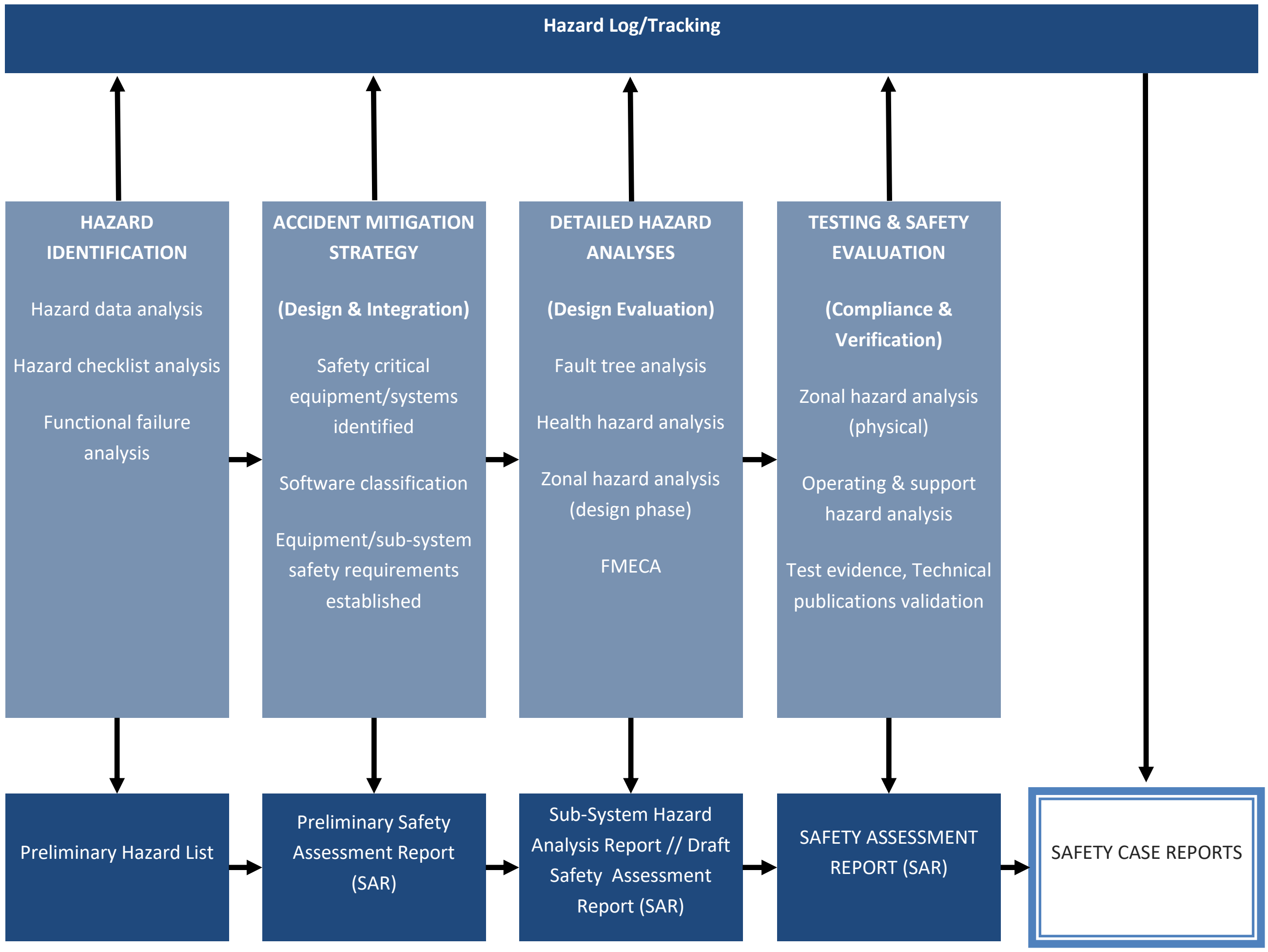

Figure 42: System safety process diagram (adapted from company documentation)

The TDG sought to identify hazards as early in the program as possible, helped by having several decades of operational and historical data from which to review. Other sources, such as the use of proprietary checklists and high-level functional failure analysis were all used in devising a preliminary hazard record. This permitted the engineering teams to identify which systems, structure, software or equipment would become safety-critical items[17].

Identifying these safety critical items early in the redevelopment effort meant the engineering team was then able to focus extra efforts on these items to ensure they would be managed and not present an abnormal safety risk in the final design. These issues were summarised into a Preliminary Safety Assessment Report (SAR).

As the design work progressed even further, specific analysis of the implications of these hazards could be carried out. This included using well-known techniques such as fault tree analysis (FTA) and Failure Mode Effects and Criticality Analysis (FMECA) to assess the implications and significance of each

[17] Any performance issues with one or more of those items would cause a safety-of-flight issue.

potential hazard. All the while, these identifications, assessments and analyses were monitored by the Project Safety Committee. The result of these analyses were documented and combined into a draft SAR for review by the Committee. Results of the analysis were also fed back into the design process to eliminate or mitigate key hazards, either through a design fix, an operational limitation, or some other workaround or solution.

Testing and evaluation is where the ‘rubber meets the road,' and where engineering assumptions are either validated or shown to be inaccurate. It was during this phase of the SSP that test evidence was used to confirm that engineered fixes to identified hazards were tenable. The results of this phase then formed the Aircraft Safety Assessment Report (ASAR) – a deliverable to the DCMA. This report was also a key input to the Safety Case Report.

14.4.4 The safety case

The Safety Case represented an integration document produced by the TDG that sustained an argument that the aircraft design was indeed a safe and airworthy under particular conditions and limitations, and thus was a cornerstone of the NAAF’s certification process of the Milvus. This Safety Case was based on several levels of documentation that built the evidence-base and was completed when the TDG’s redevelopment efforts had reached design maturity.

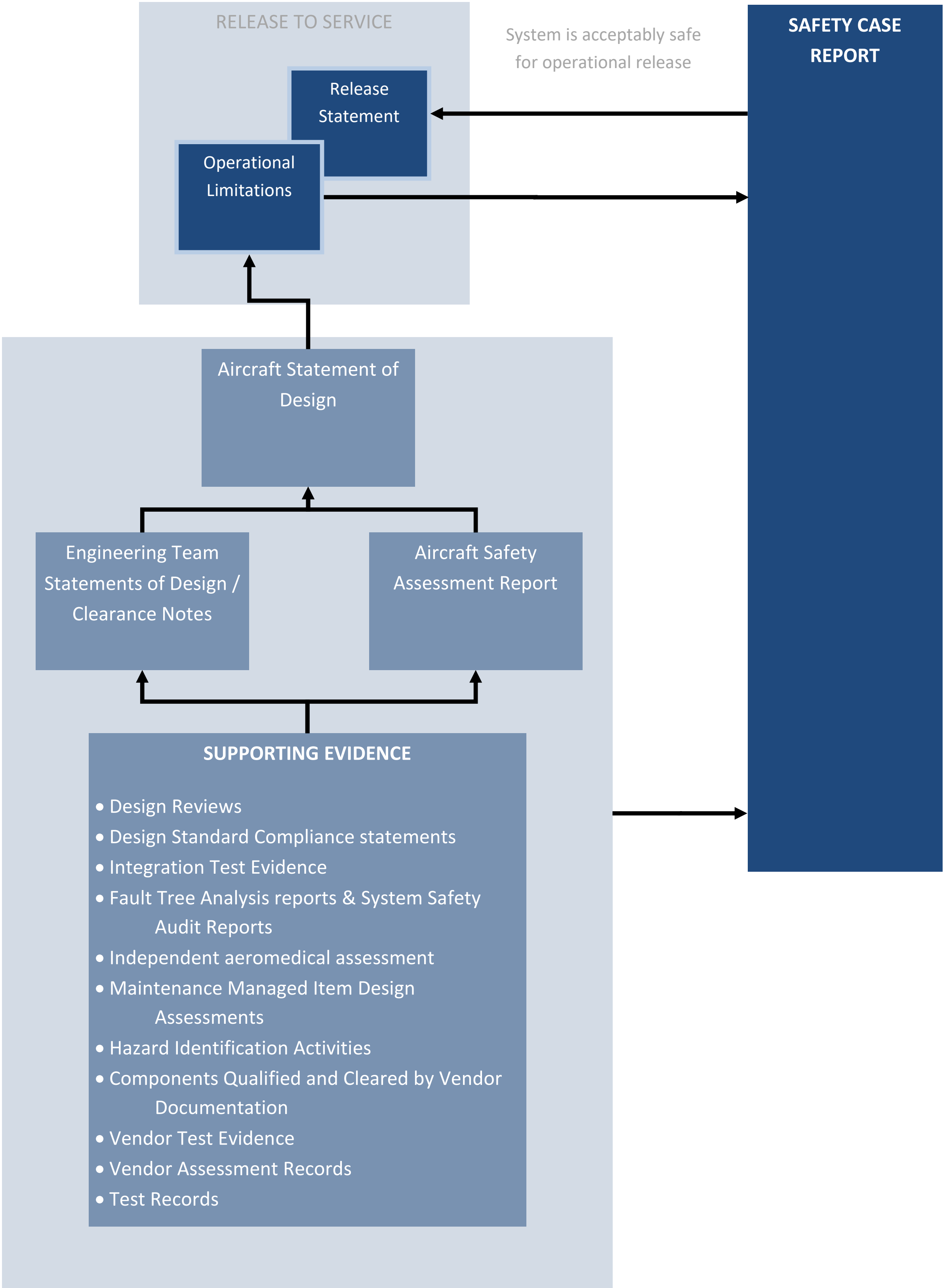

Figure 43: Purpose of the safety case report in the certification process

The Safety Case depended on wide and deep evidence base, sourced from several design analyses and outputs, including:

- **Design Reviews:** specific review conferences through the development lifecycle that acted as decision gates as to whether a product was meeting requirements and was maturing
- **Design Standard Compliance statements**: Matrices and records that indicated that the specific requirements of the design standards and regulations had been adopted and met by the design
- **Integration Test Evidence:** details of how newly installed systems had performed in compatibility testing
- **Fault Tree Analysis reports & System Safety Audit Reports:** The results of analysis and evaluations of system designs to assess the reliability and safety characteristics of those designs (part of the SSP)
- **Independent aeromedical assessment:** This was particularly to do with the incorporation of a new oxygen generation system, and were records associated with ensuring that this new system would not cause any harm to aircrew whilst in use
- **Maintenance Managed Item Design Assessments:** Records that formed part of the initial maintenance planning data package used to generate the maintenance program for the aircraft
- **Hazard Identification Activities:** Records, such as hazard logs and meeting minutes, from hazard identification efforts (part of the SSP)
- **Components Qualified and Cleared by Vendor Documentation:** Records from suppliers concerning the performance, quality, design standard and limitations of systems, parts and components designed by outside vendors
- **Vendor Test Evidence:** Records following from the above, but concerning the testing of those components
- **Vendor Assessment Records:** Details of company oversight of suppliers, including auditing and surveillance of vendor quality and ability to manufacture equipment to the required standards of quality
- **Test Records:** Data from testing of systems, and of the aircraft itself, including known issues and pathways to rectify those issues.

These detailed dossiers were then summarised into two key sets of documents – *Statements of Design and Clearance Notes* from the Engineering teams, and the *Aircraft Safety Assessment Report (ASAR)* (as described in the previous section).

The ASAR particularly focused on the design evaluation from a hazard identification and treatment perspective; for the IPD Statements and Notes, the aircraft was broken into systems or zones and outlined the key standards those systems/zones had to comply with, and how the design met those standards. The resultant Aircraft Statement of Design is similar to the IPD Statements, except that it summarised the results for the entire aircraft system, considered the evaluation results of the ASAR, and generally was the TDG's declaration the aircraft design was complete and met the necessary standards.

The Aircraft Statement of Design also led into a set of defined Operational Limitations. These limitations make clear the envelope of safe operations for the aircraft, and themselves are reflected in various technical publications for the aircraft. These limitations include the amount of payload, intensity of flight manoeuvres, types of consumables (such as fuels and oils), types of weather conditions, speeds and altitudes, and acceptable procedures for using and maintaining the aircraft. The TDG assures customers safe operations if they operate within those boundaries.

These Operational Limitations, along with the full plethora of the evidence base, were then referenced in the Safety Case Report. The key goal was to establish that the aircraft would be “acceptably safe” when used as originally intended. To achieve this outcome, the TDG put forward several arguments, including:

- History of the firm as “a competent aircraft manufacturer” by historical precedence
- That the aircraft had been developed and tested as an acceptably safe vehicle through using “accepted processes and procedures”
- The use of the appropriate design and certification standards relevant to the aircraft product
- That the design was proven through a test regime
- The complete Aircraft Statement of Design and associated declarations.

When the Safety Case Report was accepted by the DASR, the aircraft type was deemed acceptably safe for operational release. This led to the issuing of a Release Statement, declaring the safety of the aircraft within given Operational Limitations, and permitting full-rate production, as well as clearing the way for deliveries of new-build aircraft to the NAAF to begin.

14.5 The production effort

An important distinction to be drawn is that, so far, the only approval given for the aircraft by the DASR is for the aircraft design. Each actual physical aircraft of this particular model are not approved by the Type Certification process as this approval only specifies the blueprints and standard to which the fleet of physical aircraft must be produced. The process of producing an entire fleet of exact replicas is the responsibility of the production organisation, and the approval of each individual aircraft is called a Certificate of Airworthiness (CoA).

The ‘normal’ operations of manufacturing are not gone into with this case-study. Needless to say, however, that the management of the production effort involved several aspects, including:

- Planning the production schedule, working back through the production process to ensure critical tasks were performed on-time
- Managing a raft of suppliers, including the placing of orders for components and other equipment, and ensuring their on-time delivery
- Raising the appropriate paperwork, procedures, task cards and other records for production staff to assemble the aircraft
- The coordination of production staff to build the aircraft
- A program of inspections to ensure that manufactured components met the exact requirements as set out by the TDG
- A test program to ensure that assembled components, systems, and eventually the aircraft were constructed correctly and thus function as intended
- Obtaining the sign-off on all work, and delivery of the aircraft to the customer.

The Type Design Group played an important role the production effort by working with production teams to devise the processes and procedures for production (in this instance, more an amendment to already existing procedures). It also lent engineering support for non-conformances or technical issues that arose during manufacture, answered queries and provided clarifications, and provided a level of oversight to ensure that the production organisation was building the aircraft to precisely replicate the approved design.

Such activity is standard for 'normal' production efforts. However, in this case, the production effort had another unique dimension to it – that being the contract requiring that 21 of the aircraft be assembled in New Aragon at the SDG's facility. This added another layer of complexity that went beyond traditional production arrangements.

As the first twelve aircraft were manufactured literally next-door to the TDG's offices in Essenheim, the SDG was in the process of preparing for the role it would play in the production effort. The establishment of the SDG is discussed shortly, but in short, this preparation involved:

- the installation of the tooling and jigs required for assembly
- the couriering of parts, equipment, fasteners, and consumables needed during construction to be present on site when required
- The recruitment, training, and qualifying of manufacturing personnel from the local region
- The setting up of aspects of the production system that was run by the production organisation, including procedures, documentation, and records.

It's important to note that the manufacturing operation at the SDG facility was not producing aircraft from scratch. Rather, at the Essenheim factory, 21 sets of sub-assemblies were produced and shipped to New Aragon, including major subassemblies such as completed wings, tail-sets, and fuselage sections that would be attached and integrated together in the final stages of the production line to make the completed aircraft. These entire sub-sections were then shipped to New Aragon by sea – itself a journey of up to 3 months. This extra logistics step added another layer of complexity to the production effort. Once the sections arrived at the SDG facility, they were inspected, and then assembled into the final aircraft.

Various systems also needed to be either connected or installed. Once an aircraft was completed, it would then go through the process of inspections, undergoing functional, ground and flight testing, with the company project team coordinating the formal acceptance of each airframe and issuing of a CoA. Throughout the process, the TDG provided manufacturing engineering support to the SDG.

The production effort was completed in late 2001 when the final Milvus was accepted by the NAAF and entered into service.

14.6 Customer ramp-up and transition

Parallel to the development and production effort of the aircraft was a vital customer preparation activity. Unlike consumer goods where customer involvement is really only at delivery, an aircraft operator requires a great deal of support and engagement for preparing to introduce – and in some instances transition to – a new fleet of aircraft.

Lending to the fact that the customer-enterprise is made up of many sub-organisations, there were many areas of consideration for working with the customer organisation as a whole to prepare for the introduction of the aircraft. This included training, identifying the breakdown of responsibilities between provider and operator, and identifying ways of working together as the Solution became 'live.'

14.6.1 Training

Training, perhaps a more obvious need, was required for both pilots and technicians. The first cadre of pilots and technicians were sent to DefTech Global's premises in Essenheim for both the standard Type conversion course, as well as 'train-the-trainer' courses. This enabled the NAAF to run conversion courses back in New Aragon and create a recurring training system on the type for new flight and maintenance crews. To aid in the standing up of this Type-specific training regime, DefTech were required to provide the necessary approved publication sets, as well as the delivery of training aids.

14.6.2 Intrinsic challenges

During the transition from the old aircraft fleet to the new Milvus aircraft, both the customer and DefTech had to be mindful of some intrinsic challenges that emerged.

Firstly, the Squadrons had a high regard for the incumbent aircraft type that it had operated for over two decades, and were very keen on obtaining the next-generation version of this aircraft as a replacement. Obtaining this next-generation model would, it was believed, would ease the transition between fleets due to extensive experience with the Type and well-established relationships with the OEM. Hence, when the Milvus was chosen, there was a sense of disappointment and even some resistance to the new Milvus type.

The second issue was cuts to uniformed maintenance personnel. As all heavy maintenance activity was to now be undertaken by DefTech New Aragon, many of the maintenance roles within the NAAF Squadrons were made redundant. While many of these staff gained employment with the SDG undertaking maintenance work on the new Milvus fleet, it was a sensitive issue that the SDG had to be mindful of when assisting the customer in preparing for the new fleet.

14.6.3 Maintaining operations during changeover

A key challenge for both the customer and DefTech was the expectation of cutting across to the new Milvus fleet, while also maintaining an uninterrupted flying training operation, with minimal disruption on training through-put.

In part due to the intrinsic challenges highlighted above, as well as the natural impetus for the training Squadrons to focus on their business-as-usual activities, introducing a new aircraft type was not viewed as much of a priority. The daily business of flying and maintenance meant that there was an expectation from the Squadrons that the new fleet would be introduced with ease, and that 'day-one' reliability of the Milvus would either match or exceed that of the incumbent aircraft type. As Chapter 16 reveals, this wasn't fully the case.

14.6.4 Defining roles & building communications for long-term relationship

An essential foundation for the Solution was establishing clear lines of communication and information sharing between the SDG and the various elements of the customer organisation, as well as clearly defining the day-to-day boundaries between Solution provider and customer.

Previously, the Squadrons had performed most of their own maintenance and operations support activity, reaching out and sharing information with other Defence groups and agencies as required (however, still within the customer enterprise), with all the control of that activity under the one command structure. Under the new Integrated Solution arrangement, however, information would have to be shared routinely with an 'outside' organisation (the SDG) as part of the operation of the fleet, and the management arrangements would be 'split' between the provider and the Squadrons. This meant there were boundaries and overlaps which needed to be understood, particularly about the overlap between heavy maintenance and line maintenance activities. Discussions between the operator and the contractor were had to define this boundary.

Channels and communication mechanisms were required for both the Squadrons, as well as the DCMA. These included channels for the reporting of incidents & faults, the raising of queries, the ordering of parts, the requesting of line maintenance activities, and the general management of the fleet. Awareness of SDG procedures, too, was required.

Establishing a working relationship with the capability program office (CPO) within DCMA was also essential. The relationship with the CPO has been concerned more with commercial and project management matters, and less tactical fleet management; however, as the CPO moved from an acquisition focus to an in-service support office, the relationship had to be morphed to the new focus. As Chapter 16 reveals, there has been an evolution in this relationship as the Solution commenced in-service work.

14.7 Establishing the Solution Delivery Group & key infrastructure

Establishing the SDG was a critical step in the establishment of the Integrated Solution as it is the key entity that 'brings the Solution to life'. Whilst the Unit's development process was considerable, it was helped significantly by DefTech's long-term presence in New Aragon, including relationships with the New Aragon Defence Department and a talent pool from which to draw from.

14.7.1 Solution support facility

One highly-visible project that became symbolic of the whole program was the construction of the Solution support facility. The facility took ten months to construct and was readied in 1998. The facility was initially used as the main production/maintenance hall for the New Aragon build program of the Milvus, but with the vision of converting it to its current role as the key heavy maintenance venue for the Integrated Solution. The main maintenance hall can accommodate more than a dozen aircraft at once and is furnished with workshops for avionics, some components, and gun/weapon systems (the hazards of which had to be accounted for in the facility design). The facility also includes a paint-shop and a logistics store.

Adjacent to the main production/maintenance hall were built contained office spaces for the Embedded Engineering Function, the desk-based activities of the maintenance and logistics functions, and Solution management staff. The facility was also built to become the headquarters of the New Aragon aerospace business group that the SDG would be a part of.

14.7.2 Standing-up the Group

However, as impressive as the Solution support facility became, the establishment of the SDG involved many other critical actions. These included:

- The assembling of a localised management team
- Recruiting staff that would be employed as engineers, logisticians, and project management and support roles
- Establishing a network of support and service suppliers, including the formal assessment process (a requirement of the contract)
- Writing processes and procedures necessary for the execution of the contract (many of these processes were deliverables as part of the contract)
- Partnering with an established aircraft maintenance firm to provide the maintenance function as well as defining its own Maintenance Management Plan (MMP) defining how the maintenance function would work
- Setting up the formal governance structures and systems, particularly for the Embedded Engineering Function (in this instance officially referred to as a Certified Engineering Organisation (CEO)) and the maintenance function (officially the Certified Maintenance Organisation (CMO)). This also involves gaining CEO and CMO approvals from the DASR. These arrangements are now subject to periodic audit by the customer-regulator.
- Establishing and initially resourcing the Embedded Engineering Function, with its own Engineering Management Plan (EMP) defining its operations
- Building relationships with the DASR and DCMA
- Constructing the Solution support facility (hangar and office workspaces)
- Preparing for and executing the manufacturing effort
- Establishing the required information technology infrastructure, including a secure network for sensitive Defence material, connectivity with key shared applications (such as the computerised maintenance system), and the development or implementation of other tools (such as documentation management systems, and the configuration status accounting tool)
- Estimating and provisioning an initial set of spare parts, including projected demand for spares early in the Solution's life
- Making arrangements for establishing a presence at the second Squadron's west-coast base, including recruiting and gaining access to facilities.

14.7.3 Building external relationships

Establishing a network of external relationships was also another key activity. The contract required that the SDG develop an approved group of local suppliers who would provide support services, such as specialised component maintenance, to the SDG. One requirement of this arrangement was a contractual and political need to maximise local industry involvement in both the manufacturing and in-service phases of the contract.

One such major relationship was with a local aircraft maintenance company that would provide the actual, ‘hands-on’ maintenance function. Subcontractor staff were located onsite and, for all intents and purposes, a part of what might be termed the ‘Solution community’ that were engaged on a day-to-day basis with the operations of the Solution. Within a couple of years, DefTech New Aragon brought out this subcontracting company and subsumed its operations and structure into the SDG.

In addition, the DASR stipulates the formal development of relationships with key OEMs involved with the aircraft. In this instance, that meant the Type Design Group in Essenheim[18], the engine manufacturer, and other major sub-system OEMs such as the ejector seat provider.

14.8 Fleet delivery and entry-into-service

One of the final – and major – steps before the Solution entered its operational phase was the delivery and cut-across to the new Milvus fleet. The term ‘delivery’ can easily signify an event; however, due to the complexity of the capital equipment involved (i.e. aircraft and associated systems), ‘delivery’ became a project in its own right. The introduction and entry-into-service of a new fleet also represents, from a customer perspective, a transitional period defined by several milestones and achievements.

Whilst the overall acquisition program was seen by the customer as mostly successful, there were some schedule issues (i.e., delivery delays). This came down to the fact the customer’s signature on the contract was completed later than expected, but without any additional schedule extension to compensate. Whilst DefTech Global sought to compress the development and production schedule, a delay in deliveries ultimately manifested.

14.8.1 The delivery process

The delivery of each individual aircraft required collaboration between the Squadrons, the DCMA, the SDG and the production organisation in a sequence of planned steps. These stages included:

- The presence of DCMA engineers inspecting the aircraft during the production process, ensuring that the aircraft was built to their level of expected quality and that issues were dealt with in a competent and thorough manner
- Final checks and inspections of the completed aircraft at the end of the assembly process by the manufacturing organisation approval holder
- A customer-acceptance test-flight of the aircraft by the Squadrons to ensure that they were satisfied with the quality and flying characteristics of the jet
- Upon the customer forming the view that the aircraft was complete and to-order, executing the formal acceptance of the aircraft. This was a paperwork exercise, transferring ownership of the asset to the customer, and making of milestone payments as per the contract

[18] Even though part of the same global company, a formal relationship had to be established

- The physical delivery of the aircraft to the customer. The first 12 aircraft required a long ferry flight involving multiple legs to fly from the production organisation in Essenheim to the customer-operator sites in New Aragon – a trip of many thousands of kilometres requiring many refuelling stops.

This process was repeated 33 times over (except for the long ferry flight for the locally produced aircraft) as each aircraft was introduced to the NAAF fleet.

14.8.2 Transitioning to the new fleet

Delivering the aircraft to the customer was an intricate feat. However for the customer to induct and start using that new aircraft type was a whole other piece of the puzzle and constituted an activity that required careful attention. This can be seen in the fact that although delivery of the first aircraft to the NAAF formally occurred in May 2000, it wasn't until April the following year that the Milvus was been fully devoted to training operations.

This was a period of transition for the NAAF, supported by DefTech New Aragon. It was a transition because the operating Squadrons:

- Did not merely introduce a new aircraft type, but became the temporarily operators of two aircraft types
- Had to assign sufficient resources and focus to maintain the existing flying training program, using the incumbent aircraft
- Had to ensure that whilst operating two types and a regular training and flying program, they did not 'drop the ball' on either fleet operation (this includes a sensitivity to operations where a close eye was kept on the quality of flight operations and managing any discrepancies)
- Had to grow their proficiency on the new type to a point where they could operate the Milvus at the same safe, repeatable tempo as the incumbent aircraft.

Introducing the new aircraft type was the point where the operator's preparations meet an operational reality, and thus presented itself as the beginning of a learning curve, both in terms of basic mastery of the aircraft, but also preparing to use it as a major teaching tool. Ensuring focus was also essential, especially as the incumbent aircraft type was requiring extra attention because of ageing issues.

14.8.2.1 A risk-managed transition

Approaching first flight under the complete operational control of the Squadron was where the rubber hit the tarmac. Whilst operated by a trained and competent crew, this would be the first instance in which the Squadron's would be operating a new type on their own (albeit with OEM support on hand).

The NAAF is renowned for its astute approach to managing hazard risk – not avoiding it, but being highly aware of it and managing it accordingly. Hence, the NAAF Squadrons did not rush into their own first sortie without a highly organised and prepared familiarisation and induction process. This included planning how to use the Milvus (initial, tailored operational procedures), which individuals would be the first cadre to fly it, which individuals would be assigned to the initial maintenance teams for the Milvus, and what types of flight profiles the aircraft would fly initially.

This preparation also showed up in the activity that the SDG was involved in. In the months following the start of NAAF operations with the Milvus, a high number of queries were received from the operator through the formal query answering process. Many of these queries were 'can we?' type questions that were more clarifications of publications and procedures as NAAF pilots and line maintenance technicians were applying their type-training to operating the new aircraft type.

14.8.3 Activating the support program

Following the delivery of the first Milvus into New Aragon, the DASR cleared the aircraft with an initial, restricted operational status permitting a limited level of operations with the aircraft. Full operational clearance (from an airworthiness perspective) was granted in January 2001.

The moment the first aircraft arrived in-country, the sustainment and support aspect of the Integrated Solution began. However, shortly after commencing limited operations, some technical teething issues began to emerge which occupied the fledgling Embedded Engineering Function.

To add to this, DefTech New Aragon faced a situation that inhibited the Company in delivering the contracted levels of availability. A global Company policy for the ordering of spares meant that due to the production and delivery delays, spare parts allocated to the in-service support operation were instead diverted to production. As the production rate of these spares was low (due to a relatively small overall production run for such items), the SDG was short on several important spares, in some instances remaining a shortage for some years after the delivery of the fleet.

Despite the delays and unstable start to the operation of the new fleet, as more of the new Milvus aircraft were delivered, the Squadrons then reduced the number of the incumbent aircraft type through the retirement of airframes. Eventually, the complete order of the new Milvus fleet was delivered by November 2001, with the incumbent aircraft fully withdrawn from service earlier in that year.

14.9 Bringing a Solution to life

Studying a complex business operation in the current day can often be an instructive endeavour. However, such operations don't come from nowhere and understanding the back-story can yield unique insights about the reason why an operation is structured the way it is and the constraints that led to its present arrangement.

This chapter has examined that the 'mere' redevelopment of an aircraft to meet a Solution is an involved process (perhaps even more complicated given its bespoke nature), and that implementing a Solution requires strong attention to detail to ensure a smooth transition for a customer. It has also shown there are many phases and aspects to establishing a Complex Integrated Solution.

However, it's only the beginning of the story.

How is a Complex Integrated Solution managed and operated? What brings a Solution 'to life'? Even with all the various elements delivered and in place, a Solution is not merely the sum of the parts. It takes human efforts and energy to activate the Solution, to 'bring it to life' and to operate it. It's these facets that the next chapter seeks to explore.

CHAPTER 15

Operating an Active Complex Integrated Solution

Case Study 1

15.0 Keeping the turbines turning

So, what's practically involved in running a Complex Integrated Solution? What defined scope-of-work, organisational structures, processes, procedures and systems bring about performance and delivery?

Given the contractual obligations outlined in Chapter 13, and the history of the Solution's development, focusing upon the way the Solution provider actually organises and arranges itself to perform is an important consideration. It's an area many studies have tended to overlook, and yet the daily behind-the-scenes routine of the Solution Delivery Group is what ultimately makes the Solution tick.

In the study of this operation, the dividing line between 'developing' a Solution and 'running' a Solution is generally the in-service sustainment activities and where the aircraft is used as part of the NAAF's training program. It's the point where the customer starts to gain benefits from using the aircraft.

Again, this case study is viewed primarily through the eyes of the Solution provider (DefTech New Aragon); however, there are important and telling findings from how the customer engages with the provider, and how it impacts the Solution's operations.

15.1 The Solution Delivery Group

While the premise still stands that the manufacturer of the Milvus, DefTech Global, provides the Solution, technically the in-service support contract – effectively the 'activated Solution' – was placed with DefTech New Aragon. In turn, DefTech New Aragon established a project team within its Aerospace Division to bring the new aircraft and Solution online, which eventually spawned the Solution Delivery Group (SDG). It is this SDG that's charged with the management and delivery of the Solution.

The SDG is structured along four key discipline-based functions:

- Maintenance Unit
- Logistics Unit

- Engineering Unit
- Service Program Management Unit.

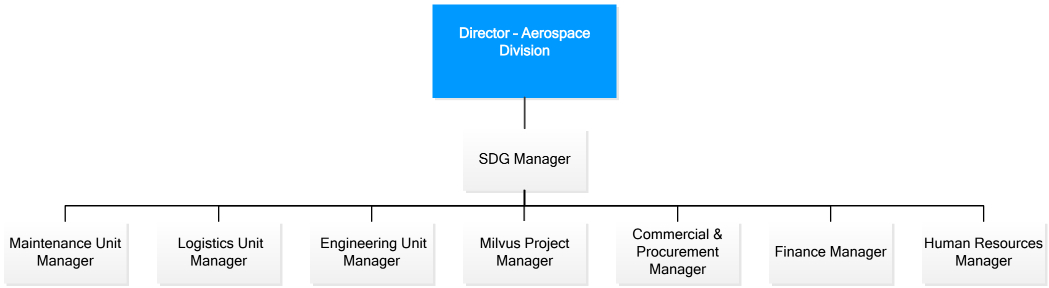

Figure 44: Solution Delivery Business Unit management structure

Each function has their own scope-of-work, responsibilities, resources and support structure of suppliers and partners. As such, each brings their unique capabilities to collectively respond as a unified scheme to the service demands and challenges posed in the Solution environment. Each of these functions are described in the following sections; however, a more comprehensive exploration of the engineering function is undertaken in Chapters 17 through 19.

15.2 The maintenance operation

15.2.1 What is maintenance?

As discussed in Chapter 11, maintenance is a critical aspect of continuing airworthiness that seeks to ensure the safety and reliability of an aircraft. However, beyond the more obvious 'hands-on-spanners' hangar activities, there are many other facets to the maintenance function which the maintenance organisation must manage. Maintenance involves many different types and varying degrees of actions, stakeholder involvement, venues, tools, and data.

From an activity perspective, the maintenance organisation is the function that physically engages with the aircraft by performing repairs, inspections, modifications and servicing (e.g., topping up of fluids). This represents the physical implementation of necessary continuing airworthiness tasks.

It's also important to note that alterations to the physical configuration of an aircraft are an extremely restricted and controlled activity; thus, the maintenance function is also the primary agency that executes physical changes to individual aircraft.

15.2.1.1 Different categories

In this case study, the customer recognises two broad types of maintenance – *Line Maintenance*, and *Heavy Maintenance*.

Line Maintenance (LM) is undertaken by the operational Squadron that operates the aircraft. Its scope covers pre-flight inspections and servicing, limited 'field' repairs (often by component replacement) and other minor tasks that can be done independently of large amounts of ground support equipment. For the NAAF, this servicing is generally done at Squadron bases, but also at other airfields when the Milvus is deployed (in such instances, NAAF uniformed staff accompany the aircraft to the forward-deployed base).

Heavy Maintenance (HM) is a much deeper and more comprehensive set of activities. The aircraft is withdrawn from operational duty for a detailed package of inspection, servicing, repairs, overhaul and modifications for period of time (sometimes months), depending on the scope of maintenance tasks to be performed. In addition, the customer organisation also recognises *major upgrades* as another comprehensive form of support activity. These include major mid-life upgrades where new systems or structural refurbishments are made, and often sees the aircraft taken offline for months, even years.

15.2.1.2 Organic or outsourced maintenance?

Some operators have the capability to perform the full spectrum of maintenance activity for their aircraft fleet. Many, however, are moving towards a blend of organic and outsourced maintenance arrangements. In this case study, the customer assumes responsibility for the Line Maintenance of the fleet, but DefTech New Aragon performs all the heavy maintenance activities. This includes all non-line scheduled and unscheduled maintenance tasks – a distinction that is important to review.

15.2.2 Key drivers of maintenance activities

Irrespective of the scope or location of maintenance to be performed, the requirement to perform maintenance on an aircraft tends to arise in one of two fashions:

- As a predictable set of taskings that are generally 'groupable' into one maintenance event. This is known as **Scheduled Maintenance**, and it tends to follow a formula outlined in the aircraft's Approved Maintenance Program (AMP).
- As an **Unscheduled Maintenance** activity. This is where an aircraft sustains damage or a defect in-service which cannot be carried forward to a scheduled maintenance visit and must be rectified before the aircraft can become serviceable again. Urgent inspections and modifications can also be a trigger for an unscheduled maintenance event.

As the bulk of the SDG's maintenance activity is scheduled maintenance driven by the approved Maintenance Program, it's instructive to take a closer look that program for the Milvus.

15.2.2.1 Approved Maintenance Program

The Milvus is maintained according to an Approved Maintenance Program (AMP) which is the technical maintenance policy for the fleet. The AMP is approved by the Embedded Engineering Function (with DASR oversight) and forms the basis of maintenance planning by the Maintenance Function. The AMP specifies:

- **Tasks:** what maintenance tasks need to be performed (making reference to the significant maintenance manual publication that specifies how the task is to be performed)

- **Maintenance Visit Levels:** Set of official designators that group together into one concentrated heavy maintenance visit each of those individual maintenance tasks
- **Maintenance Schedule:** The usage interval between maintenance visits. This is expressed as flying hours, but also contains a 'calendar backstop' as some maintenance tasks are calendar based[19], rather than usage-based.

Table 8: Maintenance Schedule Requirements for the Milvus

Servicing Designator	Usage Interval	Normalised Maintenance Duration
M1	125 hours	Line
M2	250 hours	1
M3	500 hours	3.5
M4	1000 hours	4
M5	2000 hours	12

The AMP arranges tasks, ranging from an M1 servicing package, a relatively simple inspection package, itself performed by the Squadron's own maintenance teams, through to a major M5 servicing package that involves placing the aircraft into the HM hanger for months at a time for a major overhaul. Each M-servicing package, however, specifies a regimen of inspections, checks, and tests to determine the health of the aircraft, the change-out of life-limited parts, and the rectification of found issues. This regime is reflected in Table HH, which includes a relative maintenance duration (e.g., an M5 servicing takes 12 times as long as an M2 servicing).

The usage interval refers to how many hours the aircraft can fly before requiring a servicing. The AMP moves through a maintenance 'cycle' as visualised in Figure 45, alternating through these several maintenance servicing packages. This cycle continues until 2000 flying hours is accumulated on the particular airframe, whereby the sequence is repeated.

[19] As is the case with several consumable items such as rubber seals, oils, lubricants, and other susceptible components

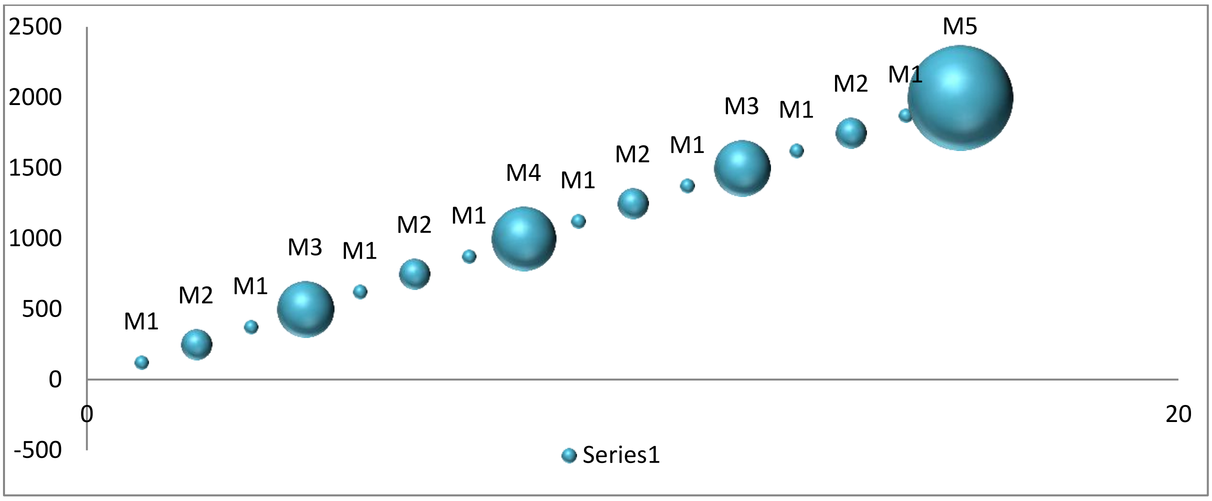

Figure 45: The maintenance cycle for the Milvus aircraft showing alternating and escalating task packages (and their respective size compared to the minor servicing package).

While this maintenance cycle is used for planning maintenance visits, planning for maintenance is not always a linear and 'clean' pursuit. Several factors come into the planning of scheduled maintenance, including the variability of the customer's flying program. This is especially during times of lower flying activity where maintenance visits might be triggered by calendar backstops, rather than hitting maximum duration between servicing. In addition to the 'M' servicing's, there is also scope for "Special servicing's" (designated with an *S*) which are planned servicing's that arise for other reasons, such as an upgrade, special/alert technical instructions from the TDG, or other activity that falls in-between the existing *M*-based servicing regime.

15.2.3 The Maintenance Unit

Given the large scale and quantity of work to be performed on the aircraft fleet, an effective organisational function to perform and manage maintenance is essential. This is not just merely an organised workforce to execute a fixed maintenance program but represents an interventionist capability to fix problems and get aircraft flying again safely. As such, the Maintenance Unit is a key part of the SDG's make-up and represents the primary 'hands and feet' of the Company to keep the fleet flying.

The Maintenance Function is not merely composed of the capability to execute maintenance tasks (namely licensed personnel with the right tools, equipment, facilities, procedures, and data) but to coordinate them too. This means the Maintenance Unit possesses the ability to plan maintenance work packages and maintenance visits in the most efficient means possible. Resource allocation, critical path management, and task sign-off coordination are required to ensure not only a quality job is performed, but that the aircraft is also returned to the customer for use in a timely fashion.

As such, this function requires a great deal of organisation, rigor, and coordination, something that's reflected in its Certified Maintenance Organisation (CMO) status.

15.2.3.1 The Certified Maintenance Organisation

Before being able to discharge maintenance activities, the SDG was required to gain the status of a Certified Maintenance Organisation (CMO). Without this approval, the SDG would not be able to operate the Solution. The terms of the contract also require the SDG to maintain and hold this approval status with the CMO audited on a periodic basis.

The bestowal of CMO status by the DASR follows a process of checking and approving a management system that is designed to ensure all regulatory requirements are met. This management system is multifaceted and includes:

- Organisational structure, profile and reporting structure, including defining management responsibility and accountability
- Personnel training and qualifications, including responsibilities, authorisations, licensing, and the certifying of maintenance work
- Key maintenance processes, including the management and change control of those processes
- Maintenance publications and data
- Maintenance record keeping
- Facilities and security.

These attributes are combined into a management system that the CMO is audited against on a periodic basis, which in turn is the basis of the organisation's retention of its approved status.

15.2.3.2 CMO structure

A key premise of the approved status is clear lines of authority and this is reflected through a designated Accountable Manager (AM). The AM's role is to ensure that:

- the CMO is suitably resourced to manage and conduct maintenance activities to approved standards;
- approved processes and procedures are adhered to; and,
- any issues that affect the quality of maintenance are promptly addressed.

Reporting to the AM is the Senior Maintenance Manager (SMM). In this organisation, there are two SMM's (one for each site venue). The SMM's role is to assume overall responsibility for the execution of the maintenance function of the CMO, including monitoring of issues that affect airworthiness, and the authorisation of personnel to perform maintenance activities.

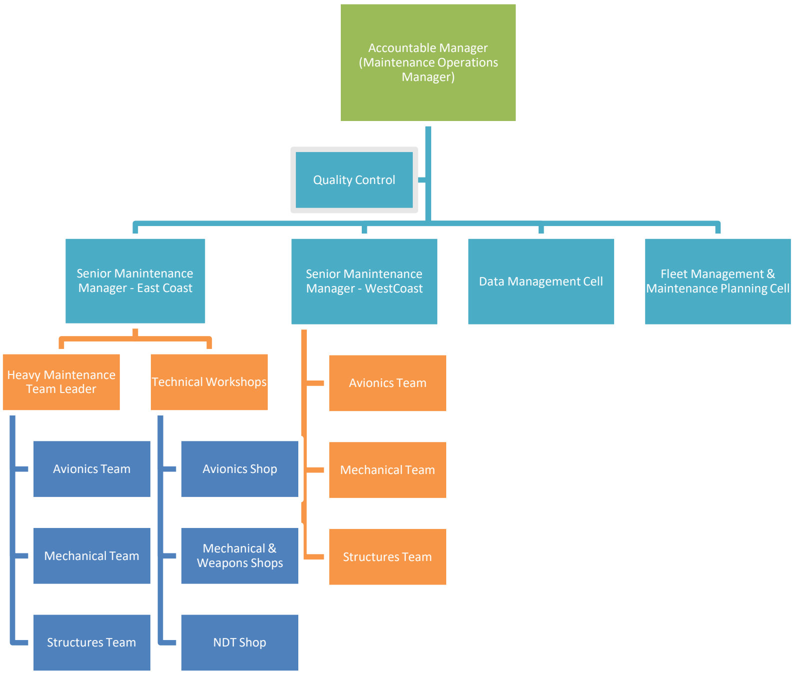

Figure 46: CMO structure

15.2.3.3 Control of maintenance

The management system requires clear mechanisms and methods to control the performing of maintenance on the fleet of aircraft. This includes:

- Who has access to the aircraft
- Who has permission to undertake physical maintenance actions on an aircraft
- What publications and information is used to undertake those actions
- Who can certify and "sign-off" on maintenance actions (declaring them complete and safe actions),
- The keeping of records to reflect work undertaken on the aircraft.

A strict licensing regime is applied in the CMO environment, so much so that unless one has the necessary qualifications and approvals, one cannot even unfasten the simplest of screws and fasteners on the aircraft. The licensing regime is set-down by the customer-regulator, and is ultimately the responsibility of the Accountable Manager, with the day-to-day oversight a key part of the SMM's role.

15.2.3.4 Maintenance processes

Maintenance management processes and procedures are another critical element of this management system, and cover a variety of matters, including:

- Which publications, instructions, orders and other data must be followed when undertaking maintenance
- Means of interacting with the Embedded Engineering Function (formally the Certified Engineering Organisation) when technical issues arise

- Ground-handling of aircraft
- Post-maintenance testing (both on-ground and in-flight)
- Certification and release-to-service processes once maintenance is completed
- Calibration and management of tooling
- Controlling Foreign Object Damage
- Standards for measuring and testing
- Managing Carried Forward Unservicabilities
- Reporting of defects and incidents
- Fitment of equipment procedures
- 'Cannibalisation' policies (the taking of serviceable part(s) from one aircraft in maintenance, and transferring them to another aircraft)
- The quarantining and/or disposal of faulty equipment
- The suite of record keeping for all maintenance actions.

These processes and procedures are separate from the actual specific tasks for the Milvus. Whereas the aircraft's maintenance manual specifies precisely how tasks are to be conducted on the aircraft or aeronautical product, these organisational procedures and processes cover how maintenance is coordinated and managed within the Certified Maintenance Organisation.

15.2.4 Managing & performing maintenance

Each maintenance visit has a lifecycle of activities that involve a broad and comprehensive array of tasks. The key phases are:

- Pre-planning
- Induction
- Strip
- Inspection
- Repair
- Rebuild
- Test
- Delivery.

The following descriptions highlight some of the more managerial aspects of the maintenance process (except maintenance planning, which is explored in more detail shortly under 'Service Program Management').

15.2.4.1 Aircraft induction & strip-down

When the aircraft is handed over to the SDG (literally toed across the airfield), the SMM will allocate a maintenance team to the aircraft that will remain with that individual aircraft until the maintenance visit is completed. The documentation package is also issued to the team. The maintenance team also undertakes an induction review of the aircraft, undertaking a series of functional checks.

Especially for major servicing's, the AMP calls for an extensive inspection program of the aircraft, and to achieve this, much of the aircraft must be stripped-down/back to gain access to critical aspects of the aircraft. In some instances, this may involve removing a panel; in others, it can involve the complete removal of primary structure and systems, such as wings and engines. Specific equipment, such as pumps, avionics equipment and weapons systems are also removed from the aircraft and attended to either in specific workshops on-site, or sent to the original equipment vendor for maintenance (an activity coordinated by the Logistics Function). This disassembly process is defined in approved publications.

15.2.4.2 Inspection & repair

A regime of inspections, primarily based on zones, is specified in the maintenance manual suite. These inspections are to determine what level of repair is needed on the aircraft, with a particular focus on breakages, corrosion, and cracking of the structure and components. Discovered defects (that are beyond normal wear) are reported to Engineering for investigation, and where the repair of fault or damage is beyond the parameters of repair guides, is also referred to Engineering for a solution to be found by them. Where components are required to replace worn-out items, these are ordered, through the Logistics Function, for delivery. All inspection findings are recorded.

It is at this point that a clearer understanding of the actual work involved with the maintenance visit becomes evident. A meeting with the customer will be coordinated to inform them of progress and issues found, and also to provide any re-estimates of when the maintenance visit will be completed, and the aircraft returned to service.

Once defects, damage and other repair needs identified, the maintenance team can begin the task of rectifying the issues. For those that fall within parameters set by approved repair manuals, these can be undertaken without additional Engineering support. Components can also be replaced when they arrive. However, one potential hold-up is out-of-scope rectifications where the Embedded Engineering Function must provide a response. Only until the EEF has provided a solution can the maintenance team perform the actions set out in specific instructions developed by the EEF. It's a process discussed further in Chapter 17.

15.2.4.3 Rebuild, test & delivery

Once inspections and rectifications have been carried out, the aircraft is reassembled. It's then subjected to a set of post-maintenance functional tests and checks defined by the aircraft's maintenance publications. It is at this point that the team-leader undertakes a review to ensure that all documentation and record keeping for the aircraft maintenance visit has been completed and entered into the computerised maintenance system.

Upon completion of this review, the maintenance team performs an additional ground inspection of the aircraft to ensure that is has been reassembled correctly, and undertakes a series of functional checks. Whilst conducting these inspections, the maintenance team leaders coordinates details with the customer-operator of undertaking a post-maintenance test flight. Once released from the hanger for this flight, the customer aircrew fly the aircraft through a series of checks, including a general 'shake-down' of the aircraft, ensuring that the maintenance process has produced a refreshed, high-quality and safe-to-fly aircraft. Any identified issues are recorded, reviewed, and actioned by the maintenance team. Upon completion of any rectifications, the aircraft is deemed to have reached the end of its maintenance visit, and the AMO prepares for the delivery of the aircraft.

The final steps before handing the aircraft back to the operator-customer involve coordinating a final pick-up/delivery date, preparing final documentation that forms part of the customer acceptance of the aircraft, and the issuing of the Service Release, a document that states that the aircraft maintenance check is complete and compliant with approved procedures.

15.2.5 Not the only Hands-On Player

Whilst the Maintenance Unit is a highly practical organisational group, it's not the only physical interventionist function within the SDG. The Logistics Unit also plays a very important 'hands-on' role in supporting the ongoing success of a Complex Integrated Solution.

15.3 The Logistics Management Unit

15.3.1 Function overview

The Logistics Unit (LU) within the SDG, headed by the Logistics Manager, has a raft of responsibilities that serve both the inner-workings of the SDG, as well as provide essential service elements to the Squadrons. As the Logistics Unit is not specifically called up in airworthiness regulations as a technical function (apart from some aspects of its activities), it has greater freedoms to be mindful of and pursue commercial outcomes.

Its areas of activity include:

- Supply of aircraft components to Squadrons for line maintenance requirements
- Supply of aircraft components for SDG maintenance function
- Coordinate the off-aircraft maintenance of Repairable Items (components and equipment taken off the aircraft during maintenance)
- Provision/leasing of Ground Support Equipment, as well as other mission equipment to the Squadrons
- Manage the SDG's warranty claims
- Manage approved suppliers to the SDG (particularly of parts and repair services)
- Undertake components forecasting and purchasing
- Conduct lifecycle cost modelling on the aircraft support aspects of the Solution
- Coordinate the SDG's cost savings effort
- Document and analyse logistics records and information.

15.3.2 Supply & distribution management

At the SDG's central facility is a warehouse that contains a raft of spare parts, consumables, and components that are shipped as required to both the CMO as part of its maintenance and repair activity, as well as the Squadrons for their line maintenance needs. This includes oils, lubricants, and readily interchangeable parts.

The LU operates, effectively as a separate service, as the Squadron's spare-parts repository. The on-time provision of parts in response to Squadron request forms part of the key performance metrics for the

Integrated Solution contract. A priority band system is used by the customer when specifying a part, including:

- Low-priority with a contracted response time measured in a week
- Medium priority with an on-time response measured in hours
- High-priority, whose response is measured in half-hours.

In addition to spares, the LF also provides, on a lending arrangement, the use of certain Ground Support Equipment, such as stores-loading units and test equipment. More is discussed on this in Chapter 18.

15.3.3 Repair coordination & management

The Function also coordinates what is termed the *Repairable Item pipeline* – a service chain for repairable components and line-replaceable units (such as pumps, avionic computers, and actuators).

When a repairable component is removed from an aircraft, whether it be during scheduled maintenance, or potentially an unscheduled maintenance action where a faulty unit is changed out before next flight, the Logistics Function delivers that component to an approved vendor for repair and maintenance. The Function manages the pipeline to ensure that there are sufficient levels of the item available in the warehouse stores should an item be called upon, as well as ensuring that the turnaround time for the repair, and the price, are all within suitable parameters.

This last management item means that the Function is also responsible for managing the approved suppliers, an activity mandated in the contract with the customer. This particularly is focused on the oversight of various repair contracts with several service providers. Some of these contracts utilise a reliability-based contracting scheme, similar to the availability-based contract for the Integrated Solution, while other contracts are traditional time-and-materials based.

The Logistics Function also ensures that these vendors undertake work to regulatory standards, and deliver consistent levels of service quality. Where failure of components is within the warranty period, the LF coordinates the warranty claims for those units.

15.3.4 An essential part of the solution

Articulating the precise role the Logistics Unit plays for the SDG isn't a straightforward task. Whereas maintenance is about inspection & repair, and engineering is about proper fleet control & intellectual support, much of the logistics function's activity can be characterised as a focus on movement, flow and order fulfilment. Rather than being a particular technical function that *enables* the Solution to operate, it acts as a key, direct service-delivery conduit to the customer.

Aside from its supply responsibilities, it's a practical function that responds to several of the customer's expectations – whether on an immediate same-day basis or on a longer-term basis. However, this also means the Logistics Unit also adopts a more 'consulting'-style role by performing much of the groundwork for significant service-development insights. There is much overlap with the Service Program Management Function (described below) and the Engineering Unit (the Embedded Engineering Function) in this area. Some key areas the Logistics Function takes the lead on include:

- Lifecycle cost modelling

- Cost-Based Savings program analysis
- Component reliability analysis
- Technical obsolescence management.

15.3.4.1 Lifecycle cost modelling

In conjunction with the Engineering Unit, the Logistics Unit produces a continually-refined lifecycle cost model. This model is based on actual activity undertaken within the SDG using data that the Logistics and Maintenance Unit's collect. The model evolves with time as new data is collected. Such a model helps permit the Solution management team to undertake:

- A periodic evaluation of the costs involved with providing the Integrated Solution
- An accurate assessment of the Solution in aid of any renegotiations of the contract
- An exploration of the impact of changes to contract arrangements requested by either the customer or the SDG (for example, the lowering of the flying-rate-of-effort)

15.3.4.2 Cost-based savings program

The LU is also the focal point for a program within the SDG to monitor the costs associated with the Integrated Solution and to identify potential savings that could be made through adjusting certain practices to provide the Solution. The fruit of these efforts is shared with the customer under a cost-based savings program. The lifecycle cost modelling aids in this analysis.

15.3.4.3 Performance insights

As the Solution is awash with vast amounts of logistical data, the Logistics Unit becomes a de facto Solution analytics centre.

The LU undertakes a comprehensive process of recording many data parameters associated with the repairable item pipeline, including reliability data of the parts, time-in-repair, configuration status, and tracking of spares levels. Forecasting of spares usage is used in ongoing efforts to ensure that appropriate levels of spares are held locally and delivered on-time.

In addition, the LU undertakes an analysis of the reliability of systems, equipment, and components on the aircraft which is fed back into the aircraft's maintenance policy (the AMP) via the Maintenance Requirements Determination (MRD) process.

15.3.4.4 Technical obsolescence management

The issue of technical obsolescence is one that faces many aircraft support programs. To address this ongoing issue, the EU and LU work together to identify critical components that may either become inaccessible (i.e., no longer available for purchase), or the components become superseded with more highly performing or reliable items. This is done on a case-by-case basis.

15.4 The Engineering Unit

To support the aircraft's ongoing capacity to deliver safe flight, the contract requires there to be embedded in the SDG what it termed by the customer a *Weapon System Logistics Management* function. This is the basis of the work-scope of the Engineering Unit, the Embedded Engineering Function (EEF) for the Solution.

For DefTech New Aragon, it defines the EU's work program as:

- Configuration management
- technical publications support
- fleet management
- design approvals
- query answering.

The EU is structured under an organisational certification approval very similar to that of a civilian *Continuing Airworthiness Management Organisation* (CAMO); this approval, however, is granted by the customer-regulator. The EU's overall role is to provide technical, knowledge-rich support and administration of the aircraft fleet, ensuring its continued airworthiness and fit-for-purpose status. It also includes responsibility for the technical integrity of the other important aspects including technical publications, training systems, and other support infrastructure (from a technical standards perspective) such as Ground Support Equipment. How these responsibilities are discharged is examined in closer detail in Chapters 17-19.

When this study first started investigating the Solution case-study, the organisational structure of the EU reflected a traditional functional organisation, as shown in Figure 47, with a headcount of about 25 staff. However, central to this case study is the story of how the EU transformed itself into a different form to better deliver on its existing role, and adapt to the environment it was operating in. This account is outlaid in Chapter 19.

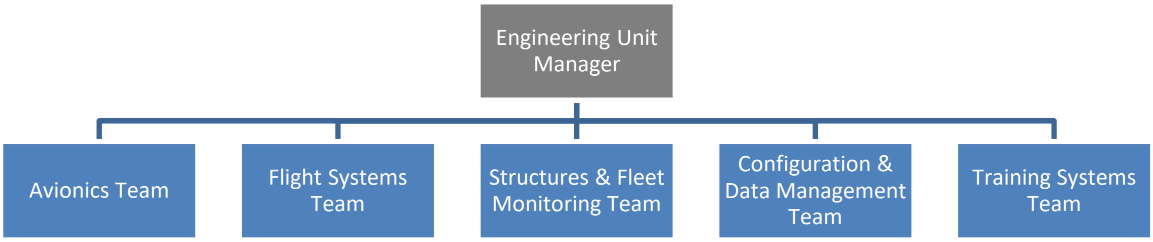

Figure 47: Organisational structure of the Engineering Unit

15.5 Service Program Management Function

While the actual DefTech New Aragon structure doesn't contain a 'service program management' function, this study does use this concept to capture some other teams and specialisations within the SDG. These are activities that are under the influence and control of the Solution's "project manager," as well as the line business unit director (the executive who runs this part of the aerospace business).

The first key block of this function is the corporate functions, including:

- Finance
- Human Resources
- Commercial & Procurement
- Risk management (which involves modelling program risks to make more effective contract changes).

The second block is that of the Solution delivery management function.

15.5.1 Solution delivery management & the Milvus Project Manager

The SDG use a curious term and organisational structure for a service program, with the inclusion of a "Project Manager" devoted to the Milvus Solution given its more comprehensive nature. The SDG Business Line manager, while responsible for the whole Milvus operation, is also responsible for the other fighter maintenance program delivered by the Unit, and thus delegates much of the management of the Milvus operation to the Project Manager.

15.5.2 Key Solution routines

Whilst the PM does not act as a service expeditor or coordinator, they do oversight the key delivery routines for the Milvus. These include:

- Maintenance planning & fleet scheduling
- Fleet management and utilisation
- Spares and operational equipment delivery
- Timely technical publications updating and delivery
- Timely query answering and operations' technical support (from Engineering)
- Capability development support (also from Engineering).

However, since the availability of aircraft is the key metric for this Solution, this section will focus on the routines and structures used to secure ongoing aircraft availability, and in particular, maintenance planning and fleet operations.

15.5.3 Maintenance scheduling & planning

While a structured and mandatory servicing schedule is enforced on the fleet, it's not a simple matter of setting a 25-year master plan of when aircraft are due to enter the hanger.

Instead, the Maintenance Planning Cell, as part of the Maintenance Unit (but also under the influence of the Milvus project manager), works with the Squadrons to 'pull' aircraft offline for scheduled maintenance. This Cell also generates the maintenance visit work package, something that is unique to each maintenance visit.

15.5.3.1 An ever moving challenge

The scheduling process is not a pre-programmed, 'static' or even entirely predictable endeavour. Instead, it's a highly intricate and dynamic activity that must balance:

- The regular maintenance and airworthiness requirements of the aircraft
- Additional requirements identified by engineering, such as additional inspections, or as part of an upgrade project
- The operational needs of the Squadrons (the operators publish annual maintenance plans that indicate an estimated schedule for fleet maintenance, subject to operational changes)
- The resource limitations of the CMO, including limited maintenance bays in the hanger, and allocation of maintenance teams to physically perform work
- The availability of the necessary parts and logistics to achieve the maintenance activity objectives
- Schedule blow-out and buffer issues from other aircraft in maintenance which puts pressure on hanger bays, maintenance teams, and potentially Squadron operations.

15.5.3.2 Preparing for the maintenance event

In conjunction with determining the 'pull' date, the Cell also starts preparing the Maintenance Unit for the arrival of the aircraft into the hangar, through three key activities:

- Reviewing upcoming maintenance work package requirements for that tailnumber
- Preparing the documentation package for the aircraft
- Organising a pre-induction meeting with the customer (operator and contract manager).

When an aircraft is 'pulled' due to a scheduled maintenance requirement, the aircraft will often require additional maintenance actions beyond the published servicing package. For example, an M3 servicing after 500 flying hours might also be the trigger or opportunity for additional tasks beyond the scope of the M3 package of maintenance tasks. The Planning Cell will examine a range of other task drivers, including:

- aircraft condition reports
- maintenance requests from the Squadrons
- modification or upgrade requirements (as provided by the Engineering Unit)
- embodiment of special instructions from the TDG
- component maintenance requirements outside the whole-of-airframe maintenance regime

- analysis of future task planning to determine that no other inspection tasks will fall due before the next scheduled servicing[20].

The Cell uses these prompts to devise a more thorough work-scope for the maintenance visit and to start planning the actual maintenance event. This includes breaking down requirements into implementable tasks, preparing a work plan to action each of these jobs, and assembling the large cadre of documentation for each activity. This third point is an extensive exercise in itself that requires the production of task-cards, work records and certification worksheets, either generated from the AMP, from the special servicing publisher, or, where a gap is identified, by the Engineering Unit[21].

15.5.3.3 A collaborative effort

Just before the aircraft is withdrawn from the operating fleet and inducted into maintenance, a pre-induction meeting is held with customer staff and is intended to confirm the maintenance schedule, work-scope, and the aircraft's current condition. This may also involve confirming that pre-induction flight tests have been completed and that customer-controlled documentation is complete.

15.5.4 Fleet Manager

Within the Maintenance Planning Cell is the Solution's Fleet Manager. The Fleet Manager performs a role that collaborates with the Engineering Unit in monitoring and continually updating the status of the customer fleet. It's the Fleet Manager who works closely with the Squadrons to understand their operational needs to work together to schedule-in maintenance in a way that limits disruptions to the customer.

However, the Fleet Manager also has a unique role of working with the customer to implement operational techniques to reduce sustainment costs with the Milvus. One key approach is the "flog list."

15.5.4.1 The flog list

As part of its airworthiness duties, the Engineering Unit gathers operational data from the operator, such as flying hours and usage profiles. It's able to use this data to generate what is termed the "flog list" – a set of operational recommendations about which aircraft should be utilised first in training missions to optimise maintenance costs.

It does this by identifying a prioritised list of aircraft that are low on flight hours, yet have a calendar backstop restriction looming. The Fleet Manager thus recommends that the Squadrons "flog" these aircraft (i.e., more highly utilise over the remaining period) before the calendar backstop coming into effect, and thus extracting the most efficient use out of the aircraft before an expensive maintenance visit is required.

In theory, both the company and the customer win; the contract stipulates a sharing a cost-savings approach, and thus any such savings are shared.

[20] So to complete it ahead of time to prevent pulling an aircraft from the operational fleet for a relatively insignificant reason

[21] Following a formal request to the EU

15.5.5 Fleet management & meeting availability

While maintenance follows a programmed rubric, it isn't an utterly predictable or 'schedule-able' phenomenon. Even the same servicing package (e.g., an M2) will not be identical the second time around, with each visit presenting its own host of failures or repair needs. This is one of the reasons why meeting availability demands and customer expectations is an ongoing challenge for the SDG.

Erratic unscheduled maintenance arisings, plus sporadic customer requests for specific aircraft tailnumbers to be available by fixed deadlines (e.g., the flight trials aircraft), compound this challenge. As such, the Fleet Management role within this Service Program Management Function must operate at the crossroads of the Maintenance Unit, the Engineering Unit, the customer Squadrons, and the business interests of the SDG to find ways of reducing disruptions and meeting availability goals. Finding workarounds, such as delaying the induction of an aircraft close to maintenance (but with some 'slack' in the number of flyable time before the aircraft must be grounded), or staggering maintenance visits, is thus an essential service program management routine.

15.6 There's more to uncover

This chapter has presented much of how the SDG organises itself to deliver against its contractual obligations, including its organisational structure and core routines. It has also highlighted the nature of the business activity it engages in and some of the realistic challenges that it faces. In particular, the significant, disciplined rigor that it must exhibit when conducting maintenance (a highly controlled and documented activity), balanced with the adroit flexibility to meet its customer's dynamic needs.

However, there's more to be uncovered. The Milvus Solution is more than a maintenance operation, and encounters many nuanced, complex, and dynamic challenges, on both a daily, but also long-term basis. This is the focus of the next chapter.

CHAPTER 16

Learning from the Early Years of the Solution

Case Study 1

16.0 Not all smooth flying

This Chapter focuses on the early years of the Solution, including the initial performance results, as well as key lessons and developmental activities undertaken by both DefTech New Aragon, and the customer, to improve the Solution and its associated outcomes. As this chapter reveals, establishing the Solution wasn't a mere 'set-and-forget' situation; rather, it emerged as a scheme under continual development.

16.1 Customer capacity to achieve flying hour target

The initial specification for achieving 9000 flying hours each turned out to be an ambitious target, not so much for the SDG, but for the customer organisation. Irrespective of aircraft availability, the highest the customer organisation attained to the point of this research was just under 8000 hours, with the average just above 6000 hours per year over the life of the Solution. This was due to numerous factors, mainly a lower-than-expected number of pilots passing through the training school programs run by the Squadrons, thus requiring a lesser number of flying hours for the achievement of the training program for each cadre of students.

In addition, particularly in the initial years of operation, there were issues with the number of trained Squadron maintenance staff for the Operational Maintenance function. An imbalance between the number of trainees and fully qualified and experienced maintainers meant that aircraft were remaining on the ground because operational maintenance tasks (such as straightforward replacements of interchangeable units, inspections, and lubricant top-ups) were not been accomplished. These aircraft were still 'available' from an SDG perspective, as valid Service Releases were in force for the aircraft and did not constitute a reduction in the daily customer pool of aircraft. However, the ultimate unavailability of these aircraft contributed to the ongoing non-attainment of the target flying hours, at least for the first few years of the contract.

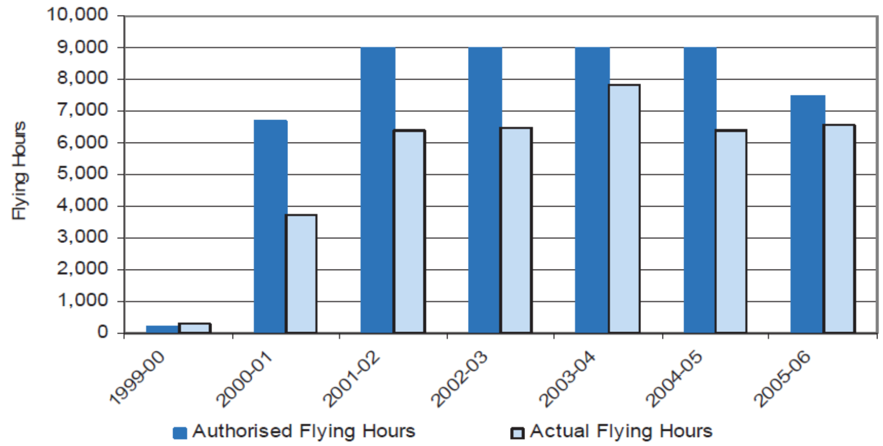

Figure 48: Flying hours attainment for the first five years of the contract (taken from customer publication)

16.2 SDG performance

16.2.1 Aircraft availability

The Integrated Solution was initially plagued with some performance issues concerning the guaranteed availability of the fleet for the daily customer pool. The results of the first contract phase (i.e., first five-years) are shown in Figure 49.

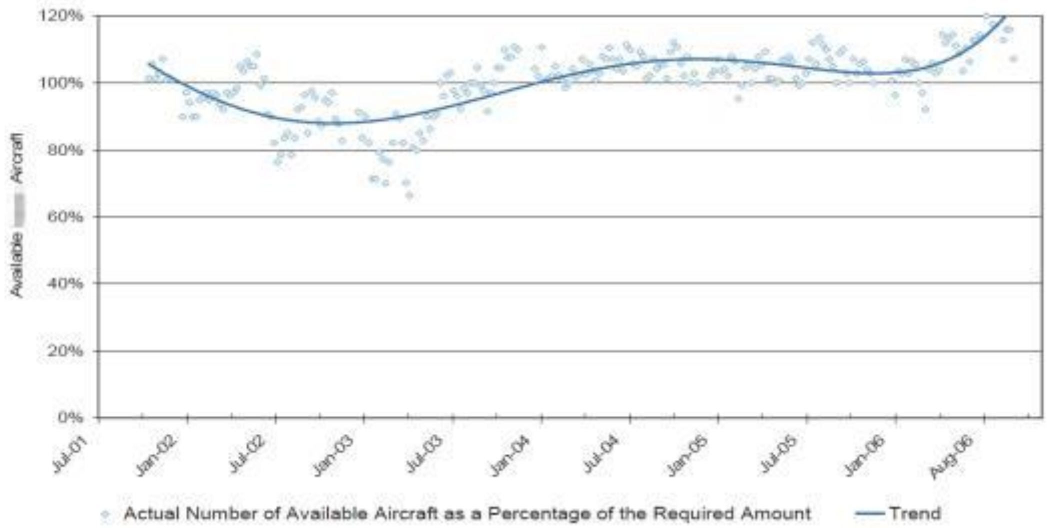

Figure 49: Milvus fleet availability during first five years of the Integrated Solution, expressed as a percentage of minimum required (adapted from customer publication)

After some years of teething issues, the issues affecting availability began to stabilise and the SDG was able to deliver a more reliable Solution. Of note are the actual data points showing a level of scatter regarding performance – the consistent level of availability differs at each reporting point, even if the trend-line shows an overall level of stability. Of note, however, was that the reduction in availability did not significantly impact the customer's capacity to achieve its flying hour targets. Even when lower numbers of aircraft were delivered to the Squadrons, airframes would still be lying dormant on the ground at the customer flight-line as they were not required. However, under the terms of contract, the SDG was still penalised for not meeting performance targets.

16.2.2 Other performance indicators

In addition to the customer daily-pool, the metrics concerning the key performance deliverables followed a similar pattern; namely, the spares demand satisfaction rate, and the Repairable Item satisfaction rate (see Figure 50). The first few years of the new Integrated Solution saw a below-standard level of performance, followed by a steady improvement in performance, eventually exceeding the minimum requirement. However, as with the fleet pool metric, performance was not consistent, with individual data points differing for each reporting period.

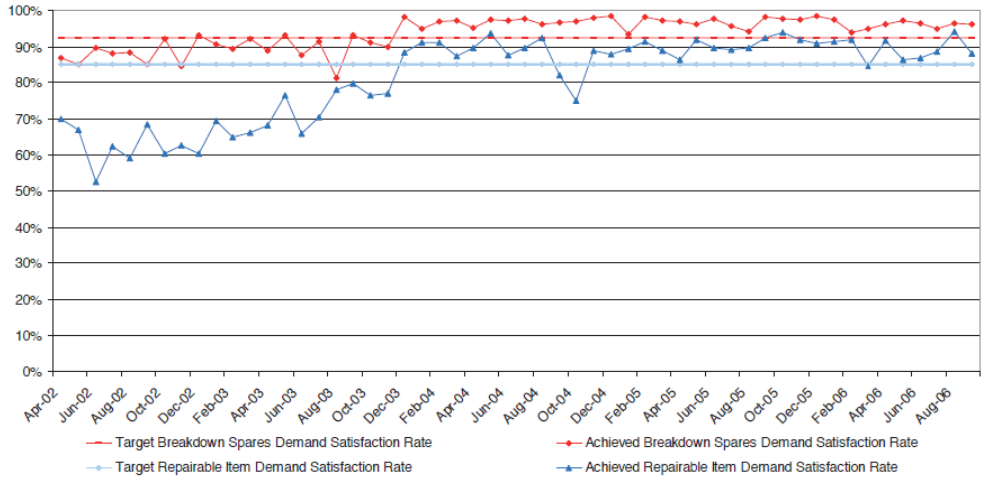

Figure 50: Performance of repairable items and supply satisfaction rate (Adapted from customer publication)

16.3 Changes to the concept of operations

DefTech New Aragon quickly learnt that it was ultimately serving two customer-operator organisations due to the way the NAAF's training scheme was designed. The customer-operator has two key courses that it puts its students through:

- An introduction to fast-jet/type-conversion course at the Squadron based in the west
- A fighter-jet tactics course conducted by a Squadron based at the 'superbase' where the SDG is headquartered.

The first course is a transition from an advanced turboprop aircraft and is the first jet aircraft that the student pilot experiences within the NAAF. It includes training regarding the systems unique to the aircraft and aims to develop the skills and aptitude required to operate a high-performance jet-aircraft. Once students have completed this initial course, they transition to the second course.

The second course takes competent pilots and turns them into fighter-jet ‘warriors’ – operatives skilled in the use of the aircraft in combat situations. This includes the use of advanced weapon systems, developing the aptitude for combat operations (as opposed to flying operations), and applying contemporary airborne combat tactics. This course is broken down into various elements and mission-types whereby students learn and practise tactics associated with air-to-air combat, air-to-ground combat, fleet (naval) support operations, and other combat activities. Once students have successfully completed these courses, they’re then sent to conversion units across the NAAF for front-line combat aircraft types whereafter they become active combat flight crew ready to undertake ‘real’ missions in service of New Aragon.

16.3.1 Missing in action: The Operational Concept Document

Initially, the various roles and activities the aircraft are engaged in were captured in a customer-prepared document called the Operations Concept Document (OCD). The OCD detailed each of the roles and mission profiles the aircraft would be engaged in, the estimated breakdown of the various roles, and the payloads that were initially expected to be carried. It provided much of the assumptions around which the Integrated Solution was devised.

However, some years into the contract, the customer withdrew the OCD as the actual scheme of operations was ever changing with NAAF needs, and was not reflected accurately in the OCD. The Document could not keep pace with the rate of changes such as the installation of new systems, the growth of cleared payloads (such as weapons), and the expansion of tactics to be trained for. Even small changes have made a difference, such as changing the size of the cadre of students going through affects the course-stagger, which in turn affects the sequence and timing of configured aircraft as delivered by the SDG. These small, but continuous adaptations and evolutions of the training school environment subsequently have impacts not only on the logistics system that the SDG runs but sometimes on the aircraft design itself.

16.4 A more comprehensive and tailored service that expected

While the contract ‘headline’ was the five key performance metrics, it soon transpired that other service-orientated deliverables were required. Namely, the provisioning[22] and installation/attachment of specific mission equipment suited to exact mission requirements for various fleet-wide training regimes or campaigns.

As such, the SDG is not merely engaged in delivering the same ‘bare’ airframe to the customer every day but is also engaged in providing aircraft equipped with the necessary payloads as suited to the courses that students are put through. This involves supplying or fitting role-specific payloads in key configuration types for use by the Squadrons at given periods. For example, the air-to-ground course involves the provision and attachment of practise bombs; the air-to-air configuration requires the

[22] The equipment is owned by the NAAF, but held by the SDG in preparing an aircraft for a particular role, as per Squadron requisition.

attachment of missiles; the fleet support role requires the fitment of fuel tanks to extend the aircraft's range.

These courses are run as operational requirements dictate; as such there is no strict annual schedule or plan to which the customer operates, meaning that the SDG needs to respond promptly to customer requests. It also must coordinate how many aircraft are allocated to a particular course (e.g., air-to-ground), as courses are run with overlap between groups, as shown in Figure 51. Whilst a change-over does not take long (generally less than a day), it still forms one of the dynamic inputs to the Fleet Management function (in addition to maintenance, upgrade, modifications and inspection requirements). 'Dynamic' because there is a moving dependency on the customer to indicate when a reconfigured aircraft is needed, itself not known until the training course has been successfully completed, and can be impacted by a series of factors, such as weather, system unserviceabilities, and the need for students to re-practise certain missions.

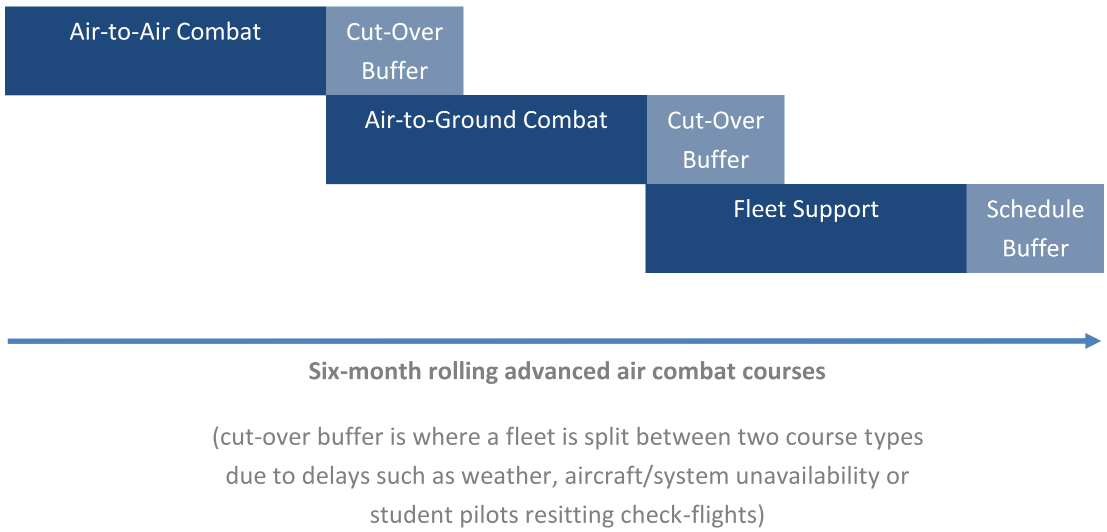

Figure 51: Stagger of NAAF training courses

16.5 Aircraft reliability & usage profile

As the NAAF's Milvus fleet is a derivative of a type used by many countries around the world, the expectation was that the fleet would operate to high levels of reliability from day one. The reality, however, was mixed. Although generally high levels of sub-system reliability were experienced, there was a lack of consistency across the fleet which affected whole-of-fleet reliability. It took some years for the reliability issues to stablise, longer than the expected 'bathtub' curve.

16.5.1 Fleet-wide groundings

Many aircraft types, at some point in their life-of-type, experience some grounding episode where the Type Certificate or Service Release is temporarily revoked. The particular model of the Milvus used by the NAAF has experienced a handful of fleet-wide groundings.

One instance involved issues experienced with the engine, triggering a fleet grounding. A critical manufacturing defect in the wing-attachment structure which affected the whole fleet also triggered a significant grounding for several weeks. In both cases, the grounding was required to undertake an investigation into the issues and to determine a fix to the problem.

16.5.2 Operational profile & structural life usage

As the two sub-fleets (ie, the two Squadrons) are used for different purposes, the aircraft are themselves subject to different loading patterns and usage profiles which in turn affect the demand on maintenance and logistics support. It soon became apparent that the east-coast Squadron 'pushes' their aircraft more aggressively than any other operator of the Milvus. This includes carrying above-normal (although within limit) payloads on-wing which also adds to the stresses on the aircraft.

Each Squadron, however, has their nuances with regards to the 'use and abuse' of the Milvus. The west Squadron has a fast operational tempo with a high-sortie rate, although the operations are a little less aggressive due to the training style. The east Squadron, on the other hand, tends to have a lower sortie-generation rate but pushes the aircraft to the edge of the permissible envelope during missions, demonstrating an aggressive operational profile. For the west Squadron fleet, the SDG sees the aircraft coming in for maintenance more often due to hitting the flying-hour limits quicker. For the east Squadron, however, maintenance is less regular, but when aircraft do enter for service, they require closer attention for fatigue cracking due to the usage profile. Thus, these usage factors have a direct bearing on the size, and thus cost, of maintenance activity for the aircraft.

16.5.3 Environmental factors on sustainment costs

In addition to the usage profile of the Squadrons, sustainment costs are also driven by the physical background environment that the fleet operate nearby: coastlines and open seas. As such, the SDG has noticed a higher level of corrosion on the fleet compared to other international operators of the type. Rectification and prevention of such corrosion thus pushes up costs associated with sustaining the aircraft. Even the airbase venues are a factor. The two bases are known for a reasonable variation in temperature and rain patterns throughout the year. Whilst not the most extreme of cases, the change between hot and cold seasons has been identified as adding an extra level of complications for managing the airframe type, both from a corrosion perspective, as well as managing some systems (see Chapter 18 and the account of the APU).

16.6 Developing the provider-customer relationship

Initially, the SDG had a limited level of contact between itself and the necessary units across the customer enterprise. To improve the level of communication, collaboration, and interaction between the SDG and the customer, integrated working groups were formed comprising staff from the customer organisation (including Squadron and contract management), and the DefTech SDG. Eventually, five key groups were established:

- Engineering
- Training

- Maintenance
- Contracts
- Fleet Planning.

These working groups, tactical in nature, meet on a periodic basis (generally weekly) to discuss emerging issues, update each other on progress or plans for the coming period, and to find solutions to problems before they become crises.

In addition to these forums, the SDG has established two strategic forums with the customer enterprise:

- An annual Solution review meeting between the head of the Aerospace Division of DefTech New Aragon and the DCMA Unit Manager of the responsible for the Milvus (and other fighter aircraft)
- Monthly contract review meetings between the head of the SDG, the Commanding Officers of the various customer Squadrons, and the internal Milvus program manager within the DCMA.

Assessing the features of client-provider relationship is a thesis topic in itself. However, it is important to incorporate a few remarks about the status of the relationship between the NAAF, New Aragon Defence Department, and DefTech regarding the Milvus Solution. Some of the indicators include:

- The Chief of the NAAF has gone on record as stating that they are "very happy" with the aircraft type.
- A raft of customer-SDG forums exist for communication and resolve issues
- Ongoing and daily communication between the SDG and units across the customer-organisation
- A regime of data and information sharing in both directions.

However, there are still occasions when the customer relationship requires special handling. As briefly discussed in Chapter 14, there existed a level of resentment towards the SDG as it was perceived to be 'robbing' the Squadrons of jobs, and also produced a sense of incensement within the Air Force ranks about been 'told what to do' by a contractor organisation. The NAAF had has traditionally 'told contractors what to do, not the other way around.' This particularly emerged on fleet management and planning issues.

As explained in the previous chapter, the Squadrons provide a plan or estimate of the level of flying expected over the coming period, as well as operational data (mainly flying hours achieved). In return, the SDG provides a series of recommendations about how to operate the aircraft efficiently, particularly by providing the 'flog list'. In some instances, the flog-list is not used, with aircraft requiring maintenance more regularly and in a less-than-efficient way, increasing costs for the SDG, but ultimately for the customer. While the fleet-management function attempts to provide a valuable service meeting the needs of the Squadrons in the most efficient means, there have been occasions where the customer has disregarded 'win-win' advice.

16.7 An important link

Surely a Complex Integrated Solution is a 'clean,' seamless and consistent performer; that everything should run according to a tidy routine without many hurdles?

As it turns out, one key lesson from studying this case is that providing Integrated Solutions is not a linear 'set-and-forget' system that automatically responds to given inputs. It is a dynamic and evolving sphere as customer business needs change, and as the provider adapts to both customer needs for performance and business needs of efficiency and risk-reduction. It is also a sphere where the Solution provider is in a constant tussle against factors that would impinge on performance.

It's this tension which forms an instructive backdrop to exploring in more detail a critical facet in the delivery of the Complex Integrated Solution – the role of the Engineering Unit, and along with it, the Milvus' Type Design Group.

CHAPTER 17

Getting to Grips with the Engineering Unit

Case Study 1

17.0 A closer look at engineering's role in the Solution

Whilst Chapter 15 took an initial look at the various units that make up the Solution Delivery Group, it's worthwhile taking a closer look at the responsibilities and work program of the Unit.

This Chapter may come across as bit 'procedural' or theoretical due to its vaster descriptive manner. However, it's still a useful chapter to examine to better appreciate the complexity of engineering's role. It's done mainly from the perspective of the Engineering Unit (the Embedded Engineering Function), but it also devotes some attention to the role of the Milvus Type Design Group (TDG) and how it engages with the Solution.

These descriptions are then put into context in Chapter 18 where the Unit's operations are looked at in more detail.

17.1 The Engineering Unit

When this study first started investigating the Solution case-study, the organisational structure of the EU reflected a traditional functional organisation, as shown in Figure 52, with a headcount of about 25 staff.

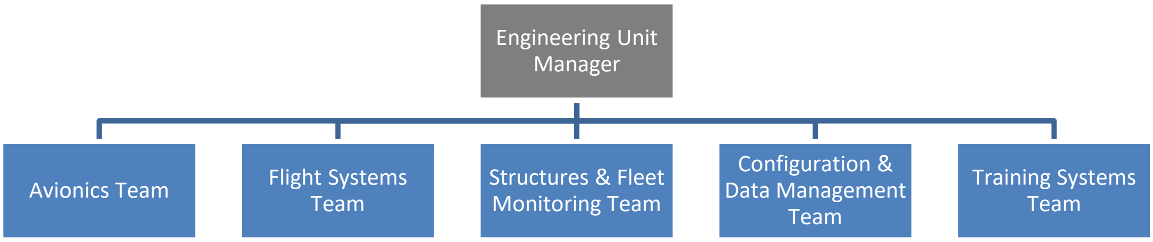

Figure 52: Organisational structure of the Engineering Unit

The Unit is headed up by an Engineering Manager who is responsible for both the management of the team, but is also the 'Chief Engineer' who has ultimate responsibility and accountability for the weapons system that includes the aircraft, simulators, other training aids, ground-support equipment, mission/role equipment, weapons integration (e.g., ensuring missiles used by the NAAF can be carried safely by the Milvus, even if responsibility for the missiles is held by another engineering management group) and official publications/documentation for the weapons system. In short, it's this position where the 'buck stops'.

17.1.1 Core responsibilities

While the core activities and processes of the EU are extensive, the key role of the Unit is espoused in one statement:

> "To ensure airworthiness, and promote availability – in that order."

The EU is responsible for ensuring the technical airworthiness of the fleet of aircraft and associated systems that combine together into one recognised *weapons system*. This includes:

- **Facilitating** and **monitoring** key information flows about issues associated with the aircraft and weapons system
- **Responding** to any safety issues with the weapons system
- **Controlling** the technical integrity of the aircraft design, including the control of any change to any aircraft in the fleet. As the controller of the aircraft's inherent safety, nothing can be added or removed from the aircraft (whether an individual aircraft or across the fleet) without the approval of the EU.

However, the EU also has a unique role to play in contributing to the availability effort, as well as providing customer/operator support. As such, the EU has four primary 'customers':

- Two operational Squadrons (the two operational units of the operator-customer) which are comprised of a flight operations unit and a line-maintenance unit*;
- Two maintenance venues (both venues are part of the one CMO/Maintenance Unit that is part of the SDG, but each maintenance line is considered separate from the EU's perspective).

[* The Squadrons are located on the opposite sides of the nation of New Aragon, and whilst part of the same Air Force enterprise, are distinct organisations with their own operational foci, imperatives and 'way of doing business']

However, whilst serving clientele, the Engineering Unit is primarily there as an authority. The EU is established and recognised (both legally and professionally) as the technical authority to the customer and SDG on all technical and airworthiness matters and is an authority which is bestowed both by the DASR, as well as the DefTech Global engineering governance system. This authority gives the Unit several official and overriding powers over the fleet, the SDG's operations, and even the customer's operations, including:

- **To ground** the fleet when necessary, over-riding any commercial concerns of the SDG, and to a certain extent, operational-requirements of the customer-operator

- **To issue directives** that must be complied with by SDG and Squadron maintenance venues,
- **To issue publications** and limitations for the aircraft that aircrew would be reckless (and likely reprimanded) if ignored.

17.1.2 Authority to act

DefTech Global has a significant product and safety governance framework as part of its global management approach. This includes clear delineation and delegation of who may undertake activities pertaining to aircraft engineering and aviation operations within the company.

The way DefTech Global decided to structure the Solution that the Type Design Group is viewed (internally) as the only unit in the Company with the power to control the aircraft design, including the recognised power to change it. Thus, changes to the design, whether modifications or even improvements to manuals, must be approved (or at least not objected to) by the TDG.

However, a wide-ranging delegation of technical decision-making powers to the EU's Engineering Manager (the designated and official head of the Embedded Engineering Function) yields a capacity for autonomy and increased decision velocity. Decisions made by the Embedded Engineering Function are, in effect, made by the Engineering Manager, and is as such is a highly responsible position.

This delegated capacity to act is derived from four sources (as shown in Figure 53):

- **The Defence Aviation Safety Regulator** (as the military airworthiness regulator): Perhaps the most important delegation, as it permits the Engineering Manager to act on behalf of the customer to manage and control the technical integrity of the fleet. As the NAAF own the aircraft, delegating control of the fleet to a commercial organisation (and a civilian) is no insignificant matter.
- **DefTech New Aragon's Engineering Director:** The Engineering Manager's reporting chain goes up to the New Aragon subsidiary's Engineering Director, via the Aerospace Division's Chief Engineer.
- **The Type Design Group's Chief Engineer:** the Engineering Manager receives a scoped, direct, company-based delegation of engineering authority from the Chief Engineer of Type Design Group that 'owns' responsibility for the aircraft type design.
- **The DefTech Global Engineering Director,** based in Essenheim: Recognition of the Engineering Manager's responsibility within the worldwide engineering enterprise of DefTech Global ensures that the Embedded Engineering Function has a level of visibility and oversight as part of the company's engineering process assurance.

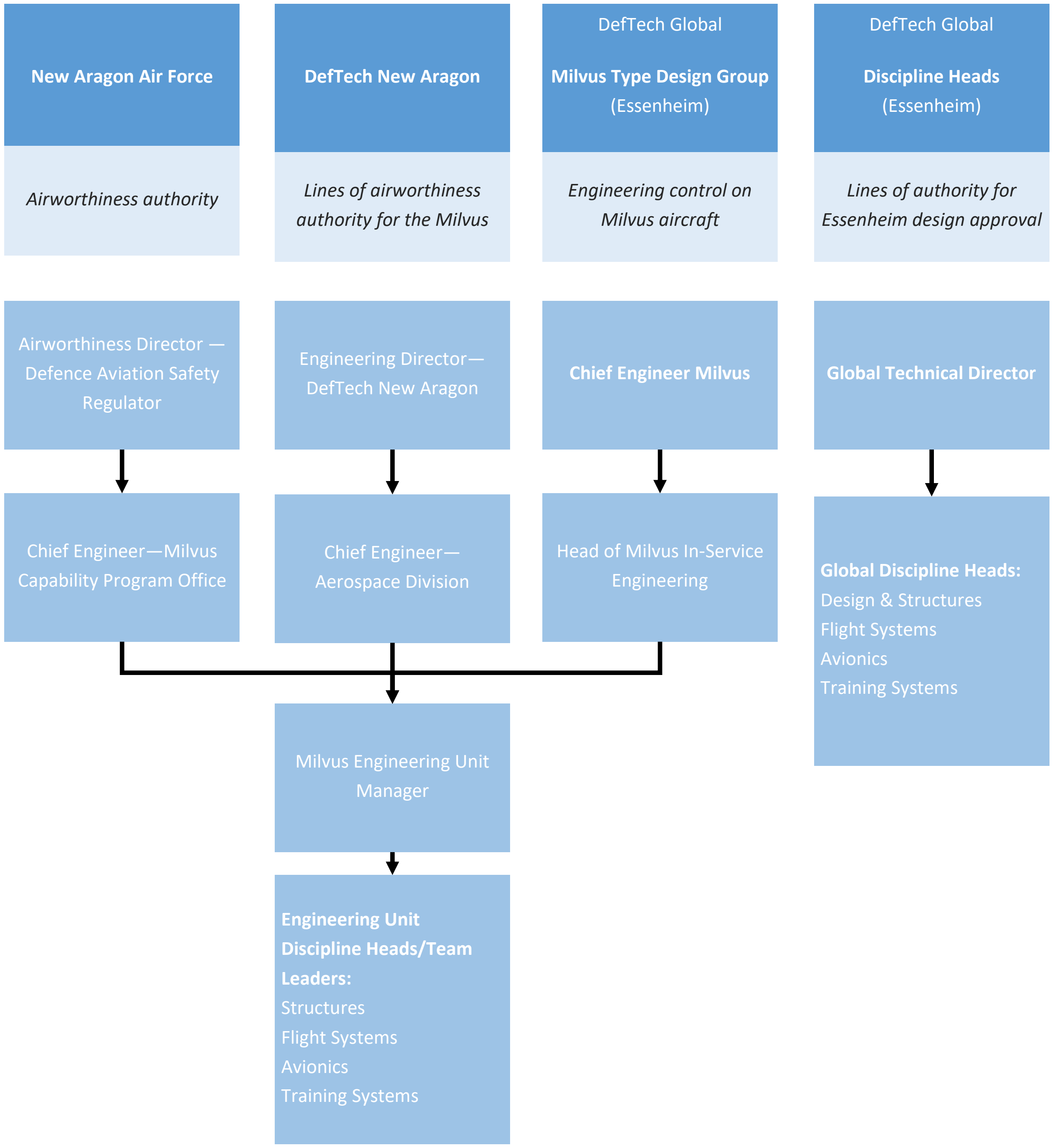

Figure 53: Lines of engineering authority for the Milvus' airworthiness management

17.1.3 Accountability

The EU operates in subjection to several oversight bodies that influence or dictate its affairs. These key stakeholders include:

- The regulator, particularly through a regular auditing process to ensure the SDG is operating according to its procedures (procedures that have been approved by the regulator organisation)

- A Design Acceptance Representative the DCMA's capability program office (CPO), who is responsible on behalf of the NAAF and New Aragon Government for the aircraft. In essence, the DAR is the 'owner' of the aircraft and has the final say on what can happen to the aircraft from a technical status or change perspective. In practise, the DAR oversights the decisions made by the Engineering Unit, as well as the rest of the Solution Delivery Group, to ensure the aircraft are managed according to customer expectations. Practically speaking, this is done via the Configuration Control Board.
- A Configuration Control Board that oversees the technical status of the aircraft. The Board is made up of Customer and SDG representatives and oversights any changes to the aircraft's design and configuration.

Additional internal scrutiny exists, too, with audits and oversight from various functions within the company.

17.2 The Unit's work program

To achieve the airworthiness and availability goal, there is a broad and diverse range of responsibilities, expectations, tasks, procedures and other activities that fall under the Unit's purview. Many of these are defined in the technical regulations that dictate much of the Unit's activities. However, its core program of work is found in two primary forms:

- Key internal, self-initiated efforts to manage and oversight its areas of responsibility (generally defined by procedures required under regulations)
- 'External' service work, responding to prompts from its constituent clients.

To achieve its responsibilities, the EU is engaged in a very broad and diverse base of activities. These include (but are not limited to):

- Reviewing all Technical Information about the fleet
- Management of Special Technical Instructions
- Deviation management
- Assess OEM concessions
- Defining repair schemes
- Managing interactions with the Design Support Network
- Technical Queries & Answering service
- Reliability Analysis
- Maintenance Engineering Analysis
- Management of Technical Publications
- Defect Report Management
- Structural Integrity Management Planning
- Type Design Control System
- Configuration Management
- Repair Scheme/Maintenance Dispositions
- Modifications Support
- Data Management
- In-Service System Safety Program Management

Several of these activities, and why they're important, are described throughout the rest of this chapter.

17.3 Services & support to constituent clients

17.3.1 For maintenance providers

The Engineering Unit provides authoritative support and instructions to the various maintenance outfits engaged to work on the fleet. Behind each of these activities, the EU analyses instructions and directives it issues to ensure that aircraft airworthiness is attained and that safety is not compromised. A significant part of this is based on the principle of configuration control – namely, the physical makeup of the aircraft cannot change without Engineering's express approval.

It does this through six main forms:

- Providing clarification to maintenance staff concerning any technical queries they may have
- Accessing abnormal damage to aircraft to coordinate the devising of a repair scheme
- Responding to any other identified non-conformances
- Providing instructions for special actions
- Managing deviations and other work-arounds
- Managing the Technical Management Plan and providing the inputs to the Planning Cell in the AMO for planning maintenance actions (ongoing maintenance requirements)

17.3.1.1 Clarifications

The various maintenance outfits engaged to work on the aircraft follow approved technical publications to perform inspections, servicing and repairs on aircraft within given parameters and constraints (for example, repairing certain kinds and levels of damage, or repairing a component using a strict procedure). However, circumstances arise during maintenance activities where the publications do not cover the particular instance, or the issue is either hazy or borderline. In such cases, maintainers are required to obtain formal advice and clarification from the EU, who themselves have access to an in-depth knowledge and data reservoir.

17.3.1.2 Repair schemes

In some instances, maintainers need to report defects and damage that is not considered normal or expected and not explicitly covered by the maintenance publications. In these cases, the EU is involved in assessing the technical issues that arise during a maintenance visit and devise a solution, such as a repair scheme, or some form of authorised work-around. In short, if it's not specifically covered in the manual, maintainers must defer to the EU.

17.3.1.3 Modification instructions

The EU is responsible for generating and communicating instructions for special actions on the aircraft (i.e., ones not covered in the maintenance publications). These are particularly used for any modifications made to the aircraft whilst the in maintenance. Modification instructions can be quite detailed, in some instances more than 40 pages of instructions, parts lists and supporting information. These modifications are for both safety and non-safety related reasons.

17.3.1.4 Deviation instructions

There are some occasions where maintainers are faced with a situation whereby they cannot restore the aircraft close enough to its original condition, and thus require EU assistance to find a solution. This may involve approving some sort of deviation from the approved condition of the aircraft. Examples include, when dealing with a significant corrosion issue, exfoliating (removing with abrasion) a higher level of material off a structural member than is approved in the manual. As the removal of material reduces the capacity of the material to withstand applied loads, the EU must assess the issue and propose an action that is still within safe parameters – in this case, performing calculations to determine that this deviation is not unsafe.

17.3.1.5 Workaround and unserviceability approvals

There are instances too when workarounds are required for the sake of timeliness, either to ensure that an aircraft's maintenance visit is completed on-time (related to the operator's expectation) or to avoid an issue with availability of the aircraft (a contractual factor). These workarounds can be in the form of leaving a particular non-critical system in an unserviceable state (for example, a part cannot be sourced in time), and thus must be released back to service with that particular system in-operatable. Whilst a list of permissible unserviceabilities is defined in the maintenance publication suite, anything beyond this must have EU approval. Other instances also involve replacing one type of component with a substitute part. The EU provides an "authorisation-to-fit" these alternate parts as a means of working around a supply (or in some instances a reliability) issue.

17.3.1.6 Maintenance requirement overruns

The EU also provides support to the maintenance planning cell, particularly for assessing requests for one-off extensions to servicing requirements. Circumstances may arise whereby an extension to the time between servicing's on an aircraft would be beneficial. This includes that the aircraft is forward-deployed somewhere and cannot return in time, through to one inspection or modification task falls right in-between major servicing's and postponing that inspection until the next servicing would save effort and the inconvenience. The EU is then involved in assessing the request to determine if there are any safety issues associated with the request. If there are no safety issues, or issues can be managed, the EU may grant an extension.

17.3.1.7 Maintenance requirements and Technical Policy Management

Whilst the EU does not plan the execution of maintenance, it establishes and updates the policy and requirements that are imposed on the fleet to ensure their continued technical integrity. It is responsible for the Technical Management Plan – the maintenance policy that is applied to the type. However, despite a fixed servicing schedule regime, the requirements of an aircraft's maintenance are a dynamic affair, and the Engineering Unit issues instructions and directives to the various maintenance planners which they are then responsible for formulating a plan for their accomplishment. This TMP management is something discussed in a little more detail shortly.

17.3.2 Services and support to the customer

The Engineering Unit engages with the customer (all customer aspects, including the operator, line-maintainer, and contract manager) on several fronts, generally as the point of contract for all non-routine technical matters. Key fronts, as well as collaborations, include:

- Query answering
- Technical investigations
- Safety data monitoring
- Scoping and feasibility studies for modifications
- Technical publications

Much of this engagement, however, does come through requests which are quite broad, covering everything from:

- Clarifications concerning content in the operating manuals
- Clarifying the operational restrictions on the aircraft ("can we" style questions),
- Requests for technical investigations into service difficulties (for example, it might be reported that one aircraft might be pulling slightly to the left in flight),
- Requests for a feasibility study on particular enhancements (such as new paint schemes).
- Technical requests for deviations from the approved design of the aircraft for operational reasons, such as the altering the pressure in the tyres to gain an operational benefit.

These requests might appear straightforward but can involve a great deal of analysis and review. A mere request to operate beyond the normal scope of tire pressures may require a complete reworking of performance calculations, reevaluating and reissuing maintenance inspections and life-limiting of landing gear components, and redevelopment of flight procedures to pull the gear up later than normal after the take-off run.

However, there are some regular/programmed activities too. Namely:

- **Operational safety information monitoring:** The EU receives copies of all air safety occurrence reports from flight crews (submitted after a safety event with the aircraft, such as a system failure), and is responsible for a follow-up investigation on technical matters. Some investigations can be minor, as they may be pilot error related, but some can be involved if responding to a serious technical failure.
- **Technical Publications:** The Engineering Unit has a data and publications team that controls and coordinates the publishing, distribution and improvement process of all Technical Publications used by the customer in their flight operations.
- **Ongoing dialogue at IPTs:** The Engineering Unit has representation at most of the provider-customer IPT meetings to be aware of issues across the Solution community, and provide input/support where necessary.

17.4 Core technical management activities

The EU is also engaged in numerous activities that are not day-to-day 'customer-facing' ones, but which still provide meaningful benefits.

17.4.1 Technical information review & monitoring fleet health

The core of the Engineering Unit's internal process for managing its technical responsibilities is the Technical Information Review routine. It ties together so much else of what the Unit does and is the basis or prompt most of the rest of its activity. It is also this process that enables the EU team to generate a picture of the health of the aircraft fleet.

The regulations define Technical Information as "all information relevant to the continuing airworthiness of and technical integrity of a configuration item (CI)," a CI itself the lowest unit defined and managed in the breakdown of an aircraft. The EU is legally responsible for at least reviewing all information concerning the technical safety of the aircraft fleet, whether that information is of no value, right through to information that may affect the safety of the next flight.

17.4.1.1 Technical information review process

The EU is obligated to register, review and assess each piece of information that is sent into the EU. The evaluation of the TI seeks to confirm:

- The applicability of the information (some are negligible, others are critical)
- The time sensitiveness of the information (some information is important, but is more for reference only, whereas other information may require an action within a given timeframe)
- The safety implications of the information (some information is useful to know, whereas others are critical to safety)
- The action required by the EU or other stakeholders.

The TIR process is overseen by the Engineering Manager for the aircraft type. This process requires that a decision concerning each piece of TI must be recorded against it, and once it has been logged, the action items are then delegated to the appropriate team. The TI may also require some sort of change to the aircraft's design, including everything from a modification, a component re-design, or even a change to the technical publications suite, itself considered a part of the design. Should this change be required, the EU is obligated by regulations to follow an approach called the Design Change Management Process.

17.4.1.2 Technical Information sources

The EU deals with a large amount of TI – more than 200 items per month. A significant amount of this information is generated by other stakeholders in the Integrated Solution community, including the maintenance venues, the operating squadrons, component suppliers, the Type Design Group, and the DASR. The types of Technical Information inputted to the EU include:

- Service bulletins and advice from OEMs

- Airworthiness circulars from National Airworthiness Authorities (NAA);
- Technical Orders and modification advice from other military operators;
- Approved modification or repair schemes
- Defence issued Airworthiness Directives;
- Information, advice, and requests from maintenance venues including:
  - defect reports;
  - reportable maintenance deficiencies;
  - improper packaging reports;
  - Maintenance policy amendment suggestions;
  - condition reports;
  - maintenance interval extension requests;
  - deviation requests;
  - notification of standard repairs to primary or secondary aircraft structure;
  - results of physical or functional configuration audits;
  - reliability analyses;
  - feedback reports from Special Technical Instructions or modifications;
  - publication amendment proposals;
  - technical substitution proposals;
  - maintenance incident reports;
  - requests for approval to install new role equipment;
  - aircraft weight and balance records;
  - aircraft stores clearance information
- Alert and safety notices from other military operators;
- Air Safety Occurrence Reports from operating units

However, this pipeline needs to be supplemented with addition information on critical issues – a deliberate search by the EU to establish certain facts – to adequately determine the health of the fleet. As such, other programs and activities are run as part of the Integrated Solution to create a greater picture, and include:

- Engine and Structural Integrity Management Programs
- Health & usage monitoring systems (HUMS)
- System Safety Program.

These activities are described separately.

17.4.2 Structural integrity program management

The fleet of aircraft are monitored through an Aircraft Structural Integrity Management Program (ASIP), and an equivalent program for the engine. These programs are deliberate and planned activities that go beyond the normal inspection and information-gathering regime of the TMP and are designed to keep a closer eye on the health of the aircraft and engine structures. The regulations depict a schema of the essential elements of an ASIP, illustrated in Figure 54, and include key attributes as:

- A process to establish, evaluate and substantiate the accepted state of structural integrity for the aircraft type (i.e., the strength, durability, rigidity, and damage tolerance parameters for the aircraft type that assure that the aircraft's structure is safe)

- A process to acquire, evaluate and utilise operational usage and structural condition data as part of an ongoing assessment of the structural integrity of each aircraft's structure
- Provide information and insights to for determining preventative maintenance, pre-emptive inspections, additional spares, estimating the future impact structural integrity issues may have on aircraft availability, and looking forward when the aircraft ceases to be economically viable to maintain due to ageing effects.

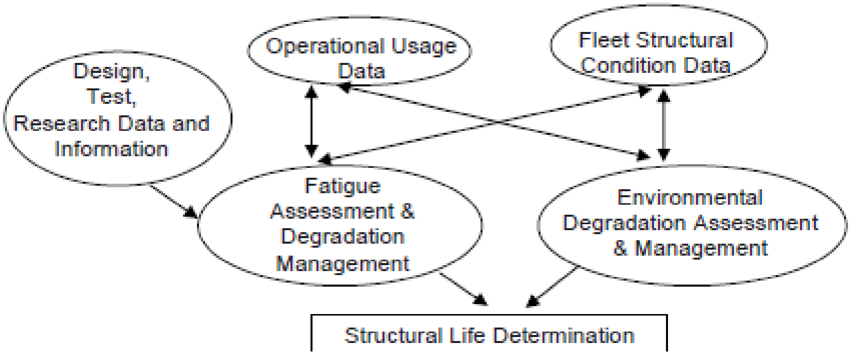

Figure 54: Information flow schema for Aircraft Structural Integrity Management Programs (adapted from customer publication)

The EU has a raft of activities that are devoted to achieving these aims, and include:

- A process of generating annual Structural Condition Assessment (SCA) reports
- Ongoing calculation of the fatigue lives of each aircraft in fleet
- Full-scale Fatigue Tests
- Usage monitoring & operational loads measurement through onboard HUMS equipment

17.4.2.1 Structural condition assessments

Structural Condition Assessment Reports are a critical knowledge product that helps the Engineering Unit, as well as the other customer and Solution provider operatives, to assess the fleet's structural health profile and status. They're used in several ways, including:

- **Track leading structural issues and causes:** The report details rates of differing types of structural issues and damage such as fatigue cracking and corrosion effects, which locations have been most susceptible, and creates a snapshot of the level of rectification work undertaken.
- **Assist in fleet life projections:** The report assesses the environmental conditions that the aircraft operates in, and projects the impact of known structural issues on long-term considerations such as life-of-type and the planned withdrawal date of the type.
- **Identify useful interventions:** It discusses proposals for addressing the more repetitive issues on a longer-term basis, such as preventative measures the aircraft repainting policy, or a program of additional inspections.

Structural Condition Assessment Reports are developed from an evidence base, including:

- defect reports
- maintenance reports and data
- flight-hours data
- operational loads and recording data
- operational deployment data (for environmental information, critical to understanding corrosion issues).

17.4.2.2 Fatigue life management

A significant source of data used to monitor structural health is via the HUMS systems built into each aircraft in the fleet that records operational loads on the vehicle.

This system involves a series of strain sensors and accelerometers located throughout the aircraft that record loading and structural strain parameters of each flight. Data is off-loaded the aircraft onto the EU's computer systems for analysis. The EU then takes this data and uses it to calculate how much of the fatigue life is 'used' after each flight.

It's also used to provide insights back to the operational Squadrons. The system can determine which pilots were flying the aircraft at the time, and thus determine who flies their aircraft more aggressively than others. This is not to discourage pilots from operating the aircraft in a more aggressive manner, as the Milvus is designed for high-g load profiles. However, this feedback can assist the operator to find ways of flying the aircraft in a manner that could potentially reduce the costs of sustaining the aircraft – a win for both the contractor and the customer.

17.4.3 In-Service System Safety Program

About eight years after commencing operations, the Engineering Unit devised a new routine to its existing work program – an In-Service System Safety Program (ISSSP). The concept, as applied in the aircraft development phase, was described in Chapter 14; however, the same principles of that program were adapted by the Engineering Unit into the in-service environment. It's a concept that's recognised in the customer's regulatory framework.

The DASR states the objectives of a System Safety Program (in-service) are:

- To assure that the aircraft system's inherent level of safety is maintained, and advocates for the generation of Safety Case Reports for design changes or assessments
- Maximise the use of System Safety data
- Maximise the use of the existing Engineering Management System (the management plan that defines how the EU works)

The program is effectively a data-rich hazard logging and monitoring activity, the outputs of which are used by the Engineering Unit and broader Solution community in continually evaluating any unidentified or not-yet suitably managed hazards that exist on the aircraft. The ISSSP is run by a System Safety Engineer within the EU, and undertakes the following activities:

- **Logging Safety-Critical Information:** Concurrent to the Technical Information Review process, information that indicates any potential safety issue (such as an occurrence or defect report) is captured by the ISSSP and recorded in the aircraft hazard log.

- **Generating Initial Dispositions Against Hazards:** When initially recorded, the log includes the initial decisions made about the TI (both short and long-term), and a risk assessment is placed against the identified hazard or event.
- **Maintaining & Updating the Hazard Log:** the register is a living repository, and more information can be added around particular hazards. Also, all members of the engineering team within the EU are encouraged to contribute to the log, through the System Safety Engineer, by providing addition information, insights or concerns they have identified that relate to the hazard.
- **Forming Insights:** These hazards are then reviewed through a quarterly forum called the *Safety Critical System review meeting*. At this meeting, the health of critical aspects of the aircraft are reviewed, the hazard log is reviewed, the 'dots' are connected (i.e., where the underlying reasons of disparate events become apparent, and emerging root-cause themes can be identified), outstanding issues and hazards are discussed, and strategies to mitigate identified hazards are devised and monitored.
- **Sharing Insights:** The hazard log process is also supported through other safety forums. The first are aviation safety meetings held periodically by the operating squadrons, where the SDO listens and contributes. The EU SSP is also connected to ongoing safety management efforts within the Type Design Group. The Airworthiness Function in the TDG coordinates the *Project Safety Committee*, where customers can share their safety concerns and identified hazards. The EU has aligned its SSP processes, so they are aligned with those of the TDG to ensure more efficient and effective information sharing.

17.4.4 Technical publications management

The EU is responsible for ensuring controlling the suite of publications that define the maintenance, operation and use of the aircraft, including (but not limited to):

- the Flight Manual & operating data/limitations
- Maintenance & Repairs Manual (for the aircraft, external stores, and other off-aircraft equipment)
- Illustrated Parts Catalogue
- and other technical manuals and publications.

These publications are controlled with the same rigour as aircraft structure or components. In fact, they are considered as part of the approved design of the aircraft, and form part of the certification of the aircraft.

17.4.4.1 Technical publications activities

This control includes:

- Coordinating and ensuring distribution to the defined recipients
- Being aware of the exact status of the publications
- Addressing any conflicts or deficiencies in publications
- Providing amendments and updates as required.

The EU also controls the annual amendment cycle with routine updates issued every six months at set times.

17.4.4.2 Publication improvement management

Occasionally, publications need to be modified, whether for simple reasons to make them more clear about certain procedures, through to changes made to the aircraft (such as new systems or weapons), through to rectifying unsafe conditions with the aircraft.

One of the key processes to manage the suite of publications is the Publication Improvement Report & Reply (PIRR) process. This process, itself a customer-defined activity using its own forms, involves a stakeholder raising a formal request for a change to a publication. This includes maintainers, engineers, air-crew, squadron support staff, or other users of the documentation. The request includes details of the proposed change, as well as the urgency level. The PIRR is assessed by the EU to determine the workload the request may involve, judging the importance and the urgency of the request (from the EU's perspective), and keeping the raiser of the PIRR informed as to the progress of their request. The EU will determine if the sought change is routine (to be included in the annual amendment cycle), is urgent (where a publication amendment is to be provided within a fixed time-frame (currently about one month)), or extremely urgent (where an amendment must be provided within 48 hours).

Because the publications suite is controlled out of the Type Design Group, the EU's scope on making changes to publications is limited. The EU can create and publish priority changes, particularly for air-crew manuals and other operational publications. The TDG must approve urgent updates that affect Deeper Maintenance activities through the Technical Query process (discussed under Design Support Network). These urgent amendments are distributed and inserted into existing manuals, with the amendment printed on conspicuous paper (to make the change stand out). In addition, these amendments are not permanent but are temporary additions until they can be embodied through the annual publication amendment cycle.

The customer-operator also has their own process of amending air-crew manuals to provide extra information or communicate changes to flight operations procedures, without approval been needed from the EU. The operator does, however, provide the EU with a copy of the changes to ensure configuration management of the aircrew publications. All other publication change requests must be undertaken by the TDG and incorporated in the annual amendment cycle.

17.4.5 Reliability monitoring and analysis

In a collaboration between the EU and the Logistics Unit (i.e., a sharing of staff), a team of three reliability engineers continuously assesses reliability, failure and maintenance data coming from various sources around the Integrated Solution community. They sources include the computerised maintenance management system (which records reliability information of components), unscheduled-maintenance taskings, as well as suggestions and feedback formally recorded from maintainers and other stakeholders. In particular, these data-sources are fed into reliability models that update the initial LSAR with real reliability performance and failure rate data.

The reliability analysis team undertakes a continual assessment of the data that is coming in, assessing the various revised reliability models, and devising a picture of the actual reliability of the aircraft itself.

They use this analysis to make formal recommendations to the Engineering Manager with a proposal to alter the Technical Management Plan to account for systems and components that are performing more poorly than expected during design. This forms a strategy to convert unnecessary and costly corrective maintenance actions (which may follow a failure that can affect safety-of-flight) to a preventative action captured during regular maintenance visits in a more efficient and effective way.

This constant reliability analysis and subsequent improvements to the maintenance program is a mandated requirement in the contract, required for EU approval (as a CEO), and is also a process defined in airworthiness regulations. Another aspect of enhancing the maintenance program, particularly improving the efficiency of a maintenance program is also covered under airworthiness regulations, defining the methodology to be used by Certified Engineering Organisations when refining the technical maintenance policy of aircraft. Whilst not a mandated activity, when it is undertaken, such organisations must follow this particular methodology.

17.4.6 Technical Policy Management

A cornerstone of the way the Solution Delivery Group manages the Milvus fleet is through the Technical Policy that the Engineering Unit imposes on the operation.

However, despite a fixed servicing schedule regime, the Technical Policy that dictates an aircraft's maintenance requirements is a dynamic affair. It is subject to changes and improvements as more information comes to light and as changes are necessitated.

This imposed Policy is made up of the following key elements:

- **Technical Management Plan** – the maintenance schedule that is applied to the type throughout its life in a periodic manner. It also includes life-limitations
- **Special Technical Instructions** – unique instructions which have some time-limit for implementation (some are immediate and can be used to affect a fleet grounding) and pertain to a serious and imminent safety issue. In some instances, these STI's can be incorporated into the TMP at a later date if an ongoing, recurring action is required, although STIs are generally used for unique, one-off inspections or rectifications.
- **Accomplishment Instructions** – beyond the 'what' and 'when' is the 'how' documentation and publications. These are generally the aircraft's maintenance manual.

Given that this Policy is the principle directive regime to ensure aircraft airworthiness, it's subject to constant changes. These changes can be triggered by a variety of reasons, including:

- The EU's Technical Information review process
- Fatigue-management predictions
- Reliability analysis
- ISSSP analysis.

17.4.7 Design change management

The need to change the fixed aircraft design occurs more than may be expected, and for many reasons, including:

- To embody a one-off repair outside the normal scope of repairs
- To embed a new system, sensor or weapon to improve the aircraft's effectiveness
- To approve operations beyond the normal, qualified envelop (e.g., operate in a hotter environment than the aircraft was originally tested to)
- To rectify reliability issues with a system by incorporating an updated component
- To approve the fitment of a replacement component because the older component model is no longer in production.

As one of the key roles of the EU is to ensure that the aircraft fleet are continued replicas of the approved design, and are keepers of this almost sacred safety-principle, the need to change that design is treated with the utmost care and responsibility with strict procedures. These procedures are a part of the Design Change Management Process, another key process that defines the EU's operations.

17.4.7.1 Minor versus Major changes

When assessing whether a change is a major or minor one, the regulator specifies in the airworthiness regulations what is considered a major or minor change:

- **Minor changes:** tend to be, as the name suggests, small changes, some which are mere paperwork exercises, without any physical change to the aircraft, or may involve approving the replacement of one type of washer with another kind.
- **Major changes:** tend to include noticeable deviations from the original design that produce a noticeable effect. Such changes include new weapons, changes to the aerodynamic shape of the aircraft, new sub-systems, redesigns of sub-systems, any change that affects the aircraft's weight-and-balance profile in a noticeable way, and notable changes to the aircraft's role, mission-profile, and environment.

17.4.7.2 Design change management process

When a change is required to the existing design, the EU will assess the exact requirement for the change, scoping the estimated level of work involved, assessing the impact and implications for other systems and aircraft users, and any other safety considerations. The EU has a limited amount of delegated engineering authority from the Type Design Group to perform certain design changes; if the proposed change is within that scope, the EU will undertake the actual design activity. If not, it will be referred to the TDG, or other Design Support Network members (see next section) for the actioning of the design task.

Once the proposed change has been designed, the EU will apply a "Judgement of Significance." This is a professional determination by an Approved Engineer about the size and scope of the actual planned change and is measured by considering what impacts any failure of the new design would have on the safety and integrity of the aircraft and its operation. The outcome of this determination affects what extent of review is undertaken.

For non-significant changes, a review is to be independently undertaken by one of the engineering team members (that is, someone who is a part of the EU but has not been involved in the development of the design change activity). For significant changes, the Engineering Manager must perform the design review. The purpose of reviews is to provide a "fresh eyes" perspective to how the design change addresses the original problem and to verify that it has been done in accordance with the correct procedures and data, and that there are no flaws in the logic, calculations or approach used in solving the problem.

17.4.7.3 Design acceptance

Whilst the EU is the 'on-the-ground' agency that controls the aircraft's configuration, it reports to the aircraft's Configuration Control Board (CCB) – a body that acts on behalf of the customer in the function of controlling any permanent and major changes made to the customer's aircraft. Although the aircraft is managed by the SDG, it is owned by the New Aragon Government.

This Board becomes one of the ways the customer exerts its ownership control over the product inherent, although the CCB is established from an airworthiness perspective, dictating what may be embodied or changed on the aircraft. It does not, however, dictate the capability development process of enhancing the aircraft's mission capabilities (this is undertaken by other parts of the customer enterprise).

17.4.8 Design Support Network management

The regulations governing Certified Engineering Organisations recognise and require the establishment of what is termed a Design Support Network (DSN) – a network of organisations that play an important role in the continued, safe operation of the aircraft. As part of the responsibility for controlling the aircraft Design, the EU needs the support and assistance of other technical organisations that have information, advice or services that assist in that endeavour. These include:

- the aircraft's designer and manufacturer (in this case-study, the Type Design Group)
- the engine manufacturer
- key system OEMs
- other technical specialist service providers (such as testing organisations, or niche engineering firms).

The purpose of the DSN is to formalise an ongoing relationship with each these key players. This includes evaluation and an audit plan (as these DSN partners are deemed suppliers). Formalising these relationships is important for the following reasons:

- Ensure a continued communication channel between the EU and the OEM/service provider, particularly important for the transmission of Technical Information such as service bulletins or safety notices
- Ensure the EU is up-to-date with technical publications that cover the items the OEM/service provider covers
- Provide the basis for continued availability of data and support from the OEM (such as technical queries and information requests by the EU). This is also important for obtaining input or support during any efforts for upgrades and modifications.
- Facilitate the operational feedback of data and information for OEM product monitoring and improvement
- Facilitate EU awareness of any impending obsolescence issues that may affect the fleet.

The key Support Network member is the Milvus' Type Design Group within the DefTech Global's operation in Essenheim. As described earlier, it is not only a supplier, but the whole Company is structured to ensure centralised product control, hence the Type Design Group exercises oversight over changes made to the Milvus. Generally, major changes are only made (or at least approved) by this player.

However, other players are also important for monitoring and controlling the airworthiness of the Milvus fleet. Thus, the Engineering Unit also adopts a relationship management role with these key providers.

17.4.9 Configuration & data management

Record keeping is a key discipline in controlling the status and airworthiness or the aircraft design, and also aids in the quality of engineering support. As such, a team of three staff are devoted to the collection, processing, storage, retrieval and if required, disposal of all information associated with the aircraft fleet. They provide the administrative support that forms the basis of the Technical Information Review process.

There are three main systems used in the managing of data:

- A customer-operated computerised maintenance system that holds all maintenance records associated with each individual aircraft, as well as details of the physical build of the aircraft (namely the serial number of the parts installed on the airframe so that physical units can be traced)
- A Configuration Status database that tracks all information and changes made to aircraft in the fleet
- A weapon system database that holds the logistic support analysis record for the aircraft type (including outputs of the maintenance system, namely component removal and reliability rates).

The Configuration Status database is the primary tool. It stores the original aircraft configuration information (namely part number serials and design release references), as well as decisions and information pertaining to decisions to alter the physical configuration of the aircraft. This way, the EU can undertake 'configuration accounting' – a way of identifying and presenting the actual aircraft build status. As such, this Configuration Status Database contains:

- List of publications, amendments (temporary and permanent updates)
- All queries and technical requests associated with the fleet
- A record of all TI received by the EU, including who responded and the response
- Lists of all Modification and engineering orders
- Defect reports
- Details about the build of each individual aircraft, including which aircraft have what modifications, and which aircraft are built with which part serial numbers
- Results of the DCMP process.

It represents the full index of items (whether physical on-aircraft items, off-aircraft items, or intellectual products) that make the aircraft what it is (and how it behaves) in that particular moment.

17.4.10 Modification project management

The Engineering Unit is also the project manager of major modifications and upgrades. Whilst it does not have the necessary capacity to actually detail-design the changes, they do coordinate requirements (with the customer) and work with Design Support Network providers to work-up, certify and embody a new modification. This also involves liaising with the Maintenance Unit to ensure embodiment can take place in a less disruptive manner.

17.4.11 Ageing aircraft management

Ageing aircraft management programs is a 'catch-all' concept that is growing in interest with operators, manufacturers and regulators alike, although represents many activities, not all of which are strictly mandated by regulations (such as obsolescence management). In short, such programs look to addressing issues that arise due to not only the life of the tailnumber (such as fatigue life and degradation) but also the life of the type. An aged type often encounters supply issues with manufacturers ending component production runs up to decades before the final aircraft type is retired from service.

This, and as the prevalence of newer technologies, can lead to obsolescence issues within the fleet. This is something that the Engineering Unit also engages with (alongside the Logistics Unit). Identifying the potential shortfall of spare parts due to the end of manufacturing is an issue the Unit seeks to manage (again, in collaboration with the Logistics Unit), to identify, source, validate, certify and embody updated components to ensure ongoing aircraft availability. This also means building new relationships with new suppliers, both regarding materiel supply, but also the provision of technical support and service for newer component designs.

17.5 Not the only engineering force

17.5.1 The Type Design Group

Depending the jurisdiction or regulatory system, many aircraft manufacturers are required to maintain some engineering organisational structure around a certified aircraft design to provide technical support to operators, monitor the safety of the certified aircraft design, and act as a single point of truth for the design.

For the Milvus, this is no different, and DefTech Global maintains a Type Design Group that provides support to operators, as well as to internal company production efforts. It's not a straightforward Group arrangement, with other reasons for its existence (and other factors that potentially threaten it); however, it's something discussed in Appendix A, itself a more detailed brief of the TDG.

17.5.2 Organisational profile of the Type Design Group

The Type Design Group for the Milvus is engaged in a broad scope of work, beyond in-service support. It's the:

- Design agency for upgrading and redesigning newer models of the Milvus (a product development role).
- Manufacturing engineering support agency for the Milvus production effort.
- Business development support agency that aids efforts to sell new copies of the Milvus (as well as services, spares, and new systems to be installed in an existing fleet).
- In-service product support provider.
- Consulting agency for bespoke services such as trade studies and data modelling activities.

To deliver on these key areas, the organisation is made up of several functions and is coordinated through a matrix-style structure. The structure changes somewhat regularly to adapt to changes happening within the program – for example, a major contract win for a redevelopment will have resources moved and structured around the design effort, and as the activity subsides, it is subsumed back into a more 'business as usual' structure.

17.5.2.1 Product governance structure

The TDG product governance structure is shown in Figure 55. The Type Design Group is headed up by the Engineering Director who is also the Chief Engineer for the Milvus and its associated systems. Reporting to the Engineering Director are delegated authorities for key aspects of the aircraft system, including:

- Flight Systems
- Software
- Structures
- Aerodynamics
- Mission Systems
- Flight Test Instrumentation
- Design.

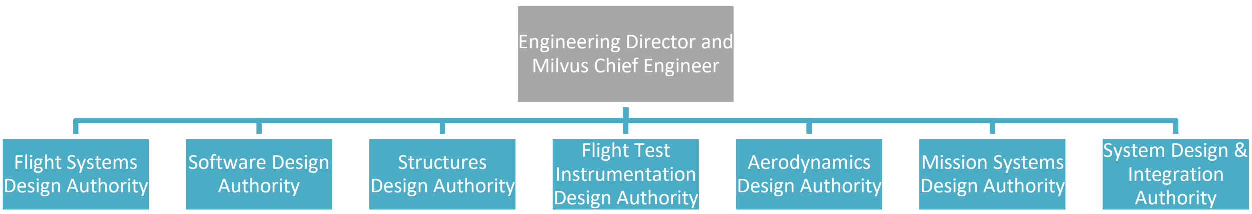

Figure 55: Milvus product governance structure, as part of the aircraft's Type Design Group

Each of these delegated authorities possesses the knowledge and competence to provide adequate oversight and stewardship for the Milvus design, with responsibility for those key functional areas made clear. Each of these areas also has a team of engineers who are tasked with various work packages for the approval of the delegated authority. However, while this structure clearly shows lines of delegated authority, it does not clearly articulate some of the greater complexities of the TDG's operations, nor does it convey a fuller sense of the responsibilities and functions that it discharges. Presenting this in a simple snapshot is not straight-forward.

17.5.3 Key functional teams

What's not reflected, though, in the product governance structure are the functional, discipline-based capability areas of the TDG to deliver against its mandate. Thus, the Type Design Group is made up of the following teams (whose work is signed-off formally via the product governance authorities):

- Weapon System Integration
- Mission Systems
- Airframe
- Test & Evaluation
- Airworthiness
- Quality Assurance
- Publications
- R&D
- Training Systems
- Production Support
- In-Service Support
- Modifications management
- Spares & Logistics
- Flight Test Group

Each of these areas is described in Appendix A. It should also be noted that the structure, size, reporting scheme and responsibilities vary from time-to-time, depending on the 'season' that the TDG is in (e.g., highly product-development focused on delivering against a contract).

17.5.4 In-service support operations

So how does the TDG provide in-service support?

The in-service support activities pertain to several customers (more than a dozen sovereign operators), each with different requirements and each requiring different levels and depth of support. Some customers undertake almost all their in-service engineering in-country without the company's assistance, whereas some are reliant on the TDG on an almost daily basis. The SDG in this case study is reasonably-to-very dependent on the TDG, although it would not be classed as extensive.

The TDG provides engineering support services for operator customer along the following key lines:

- Technical queries
- Fault investigations
- Technical instructions
- Technical queries
- Structural integrity management support
- Training needs analysis
- Modifications
- Survey & quote for major items, including upgrades
- Minor and major repair scheme development
- Accident & incident investigations.

Other forms of support are provided by other functions across the DefTech Global Military Aircraft division but are delivered through the Milvus program management organisation, including:

- Flight test engineering & operations
- Spare parts supply

Putting these activities into some context is important. In recent years, in-service support engineering has become a larger part of business for the TDG as the Milvus' production effort begins to thin out. For some decades, support engineering constituted about 10% of the TDG's work program; however, it's now trending to become an almost exclusively support-focused operation. This has some implications for the structure and form of the TDG, discussed in Appendix A (along with further details of the above activities).

17.5.5 Delivering tailored support to operator clients

So how does the TDG 'deploy' these services to meet the needs of individual (and staunchly independent) operator clients?

The TDG is a matrix organisation, with key 'taskers' being the product development, aircraft production, and customer support teams. These 'clients' feed tasks into the functional structure to be processed and worked. These points-of-contact then draw the results of those tasks out and distribute to their own constituent clients. One of these tasking-agents is a Support Engineering Group for International customers, shown in Figure 56 (the Essenheim 'home' customer has its own separate support engineering structure into the TDG).

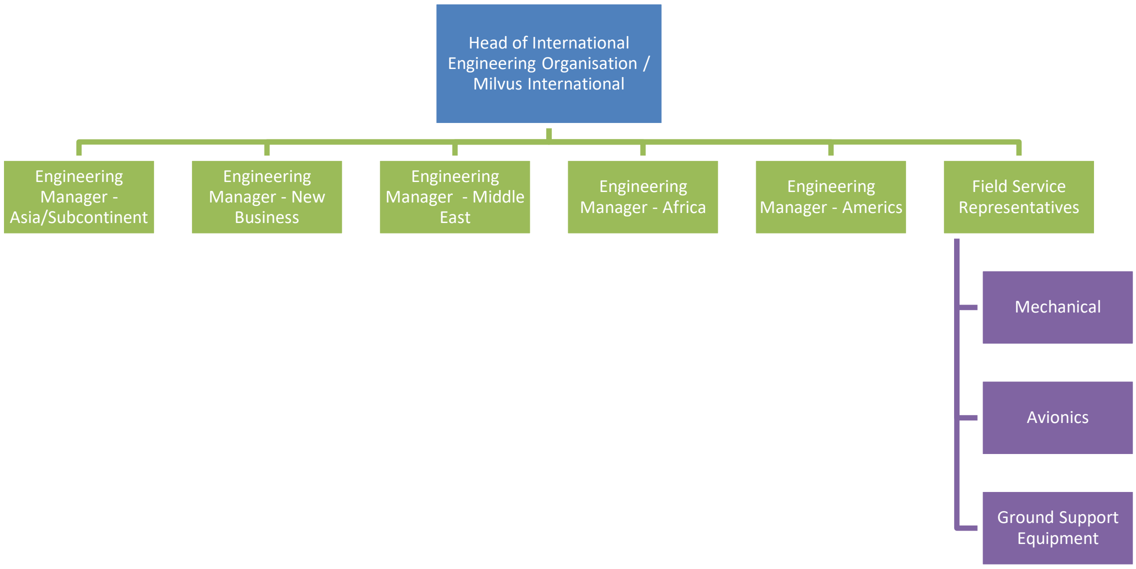

Figure 56: Milvus international customer support management structure

The Support Engineering Group hosts focals for each of the operator clients across the world. With over 15 customers of varying sizes, needs, expectations, and in this instance, political importance to Essenheim, there is a significant amount of prioritising that is required to address the needs of operators.

Customer-operators have a close relationship with their respective focals, discussing issues that they have and what they need from the TDG. These requirements are broken down into taskings which are passed onto the appropriate discipline lead for actioning. The country focals then manage the process, keeping the customer-operator informed of progress, acting as an advocate for that customer. When the tasking is completed, the focal assesses it, where required integrates it with other work generated by the TDG, and delivers it to the customer. These taskings can be everything from the need for a repair scheme, to the supply of specific advice, to a request for an investigation, through to the need for a modification. Some tasks can be less than 30 minutes in duration; some can be years.

The respective country managers also interface with other Essenheim-based staff in the Milvus Program Management organisation as required, particularly on the issue of generating new business, and spare-parts material management.

17.5.6 It gets complicated fast

The TDG structure and arrangements to provide in-service support become complex quite quickly due to several factors:

- The size of DefTech Global as an enterprise, and the distribution of responsibilities, facilities, and resources across the globe
- The limited resource capacity of the TDG, versus the competitive needs of customers
- The varying needs of customers, from new product development to end-of-life support

- The various number of sub-models of the Milvus that need to be supported (more than six separate sub-models of the type exist).

While the country focals have been proven to be a useful strategy for helping customers cut through the complexity and garner the support they need, it's not been all smooth flying for the Solution Delivery Group. With the greater-than-average dependence on the TDG, the SDG (and the EU) have had some areas of friction/drag with the TDG that has caused issues for the SDG. This is exacerbated by the fact that as all these operations are under the DefTech Global enterprise, the EU has been seen as a de jure subservient unit to the TDG.

It's an issue that's discussed in more detail in Chapter 19 on future developments of the Solution.

17.6 So what?

17.6.1 A complex work program

This Chapter has detailed the breadth of expectations, responsibilities, and activities that the Engineering Unit within the Solution Delivery Group is engaged in. The Unit's work program is broad, dynamic and complex, but also is not one that's always immediately apparent. Further still, defining the role of engineering in a product design and development context is relatively straightforward to visualise and picture; however, understanding the role of Engineering in this in-service context can be harder to envisage.

For ease of understanding, this wide-range of activities can be approximately broken down into the following key activities:

- Maintenance program management and support
- Customer-operations support
- Technical information and Configuration Management
- Design Support-Network management and operation/tasking/coordination.

17.6.2 Not the only engineering contribution

This study has also outlined the unique role that the Type Design Group for the Milvus plays in the Solution as a key partner and technical force that helps the Integrated Solution. While it operates from a different and multifaceted context, it provides an essential element to the success of the Solution. It's only when the TDG is better understood does the role of the Embedded Engineering Function become clearer.

17.6.3 But there's more to see

Whilst the above might be instructive, this chapter has not demonstrated in much detail some of the complex engineering challenges, issues, and requests that have arisen on the NAAF Milvus Complex Integrated Solution. Only then can the Embedded Engineering Function and indeed, in-service engineering as a concept, be properly understood. This is something that is explored in more detail next.

CHAPTER 18

In-Service Operations of the Engineering Unit

Case Study 1

18.0 Technical capability in action

Whilst Chapter 17 catalogues the Engineering Unit's responsibilities and work program, the actual tempo of operations was not a linear, programmatic sequencing of tasks. Further, Chapter 17 didn't give a sense of the practical issues the Unit faced on an ongoing basis, nor did it give a sense as to the volume and diversity of activity that happened at any one point in time. Rather than a purely linear, pre-planned style of work, it was and continues to be, a very dynamic environment.

Thus, this Chapter is devoted to constructing a snapshot of the Engineering Unit's day-to-day operations. It's not a 'day-in-the-life' account of the engineering team; however, it does present several real situations and challenges that the Unit had to respond to, illustrating the complexity and diversity of the Unit's operation.

This chapter examines:

- The pace of operations
- The nature of the work program (not just the types of activity)
- Examples of demands and requests placed on the EU.

18.1 Concurrent operations

It's important to start this characterisation with a critical reality check: all these activities happened *concurrently*. At any one time, the Engineering Unit sought to be across and manage several streams of information and activity, including:

- The daily receipt of about ten pieces of Technical Information for review (generally about 200 items per month), ranging from non-applicable, to severe enough to warrant an immediate grounding of one or more of the aircraft fleet. This required the EU to continually review, delegate, and action all incoming TI, plus handle the pipeline of requests for EU support or by the same process. This information would also often require an action against each item of Technical Information, such as:

  - An investigation (whether minor or major)
  - Some level of data search or analysis
  - Some form of response, whether it be a clarification to a query, through to noting a defect in the appropriate database to build-up a picture of the aircraft fleet's health, through to devising a repair scheme, through to initiating a major project such as modification

- Responding to other requests for assistance, support or technical dispositions not delivered via the Technical Information process.
- The generation of analysis and reports associated with the operation of the aircraft for review and to help generate a mental picture of the status of the aircraft fleet. In particular, the annual Structural Condition Assessment reports, as well as periodic reliability reports, are essential information products for review by SDG management and the customer.
- Support the fleet planning group to determine when aircraft need to be 'pulled' for inspection or repair beyond the normal servicing schedule due to some airworthiness matter
- Manage the Design Support Network to provide input to the ongoing processes of the EU
- Handle demands from the business-side of the SDG for finding efficiencies and improving effectiveness.

The Engineering Unit was faced with an array of challenges that were never-ending and semi-random in their nature, thus revealing another layer of the highly diverse and complex nature of its mission. Thus, this sporadic but persistent tempo of the in-service engineering environment makes for a significant management challenge.

18.2 Nature of the work program

As identified in Chapter 17, the Engineering Unit's work program was driven by two primary sources of demand:

- Key internal, self-initiated efforts to manage and oversight its areas of responsibility, mostly defined by procedures required under regulations, although also driven by data inputs from other parts of the Solution environment (both maintainers and operators)
- 'External' service work, responding to requests for determinations, input or analysis from its constituent clients, namely:
  - The maintenance venues (as part of the SDG)
  - The operational Squadrons
  - The Capability Program Office within the DCMA
  - Internal SDG units, including the management function.

While the internally-initiated work program was predominately programmatic and predictable, the external response work was highly variable and unpredictable in terms of:

- The nature of the issue
- The size of the task
- The complexity of the request
- The criticalness of the matter

- The 'smooth sequencing' of demands (e.g., a rush of requests, followed by a quiet period).

Requests and responses came in different sizes and complexities. Some were straightforward; some became projects in their own right.

18.2.1 Examples of such demands

Over the course of its operations, the EU has experienced several 'styles' of requests from various constituent clients, including requests for technical dispositions to rectify an issue, through to investigations, to feasibility studies for reliability improvement or capability enhancement.

The rest of this section looks at two key forms of minor to medium level pieces of work:

- Technical Disposition Requests, and;
- Customer Capability Enhancement requests.

18.2.2 Technical disposition requests

These were requests from a constituent client of the EU for instructions or assistance of a technical nature that needed prompt attention to restore an aircraft back to service.

18.2.2.1 Minor repair schemes

Requests for repair schemes can be relatively minor. For example, as the operational environment the NAAF operates in is conducive to corrosion, higher numbers of corrosion episodes occur on the aircraft. When corrosion forms at a deep level on the aircraft structure beyond the level stated in the repair manual[23], a formal repair scheme must be requested from the EU. Because removing material reduces a structural member's ability to carry loads, accurate analysis is required, often requiring a reference to original stressing data. Much of this data is held (in this case) only by the TDG, and thus the EU must coordinate with them in the provision of a solution to the particular corrosion issue.

18.2.2.2 Major repair schemes

Other repair schemes, however, can be significant. One such instance was when a student-pilot accidently flew their aircraft into high-voltage power lines, causing substantial damage to the aircraft[24]. Large gouges were inflicted on several locations on the wing and required extensive repair. Again, the EU had to coordinate with the TDG, through the customer desk, to devise whether the wing could be repaired, and if so, to devise a repair scheme.

As the Squadron's investigation found that the cause of the incident was negligent flying by a junior pilot, the repair work was out of the scope of the normal performance-based contract, requiring the customer to pay as part of a separate arrangement for the repair of the aircraft.

[23] That authorises the removal and exfoliation to that level
[24] The pilot was able to put the aircraft down at a local airfield after declaring an emergency

18.2.2.3 Troubleshooting investigation into aircraft handling

The EU was occasionally called upon to support investigations into abnormal issues that manifested in the fleet. One such request was following a report submitted by aircrew from one of the Squadrons that their aircraft was not flying straight-and-level when it should have been, potentially indicating a problem with flight control system on the aircraft. The Squadron requested an investigation into the issue which the EU was required to coordinate and complete.

18.2.3 Customer capability enhancement requests

As described previously, the customer enterprise, including the operational Squadrons, work in an environment that is changing, which then impacts the SDG and the architecture of the Integrated Solution. This also extends to making changes to the aircraft fleet, whether to rectify a safety situation or to gain some tactical advantage in simulated combat missions.

To support this imperative, the EU continues to receive ongoing “can you just”-type queries and requests to enhance the operator’s capability.

18.2.3.1 New equipment pods

One such request was for the trialling of a new sensor system, attached as an external payload on the wing attach points. This ‘screw-on; screw-off’ system, used by other military aircraft across the world, would provide the operational Squadrons with additional powerful sensors to use on given missions. The request for incorporation, however, was an involved job – the engineers had to determine that there are no adverse aerodynamic effects from carrying the pod, as well as determining the operational limitations that the extra payload might impose (e.g., restriction on aggressive flight manoeuvres). Integration with the onboard data and visual display systems was another involved task, requiring a significant amount of effort to make the unit work. This level of effort was especially so since the system had not been fitted to the aircraft type previously. Even just to trial the pods required full involvement of the TDG to assess, analyse and clear the attachment of the pods, and to engineer an installation arrangement so the sensors would integrate with the aircraft’s combat system.

18.2.3.2 Improved aircraft anti-collision lighting

The NAAF at one point requested investigating the incorporation of a new standard of strobe-lights. The Squadrons were investigating ways of reducing the risk of a mid-air collision as both the operating bases of the Squadrons continue to exhibit dense air traffic patterns; one of the Squadrons’ recommendations was to embody a new type of flashing strobe-light on the fleet. This required executing a design change to the aircraft, assessing any new or induced hazards associated with the change, sourcing the components, coordinating the embodiment of the modification, and performing any trouble-shooting. Whilst a seemingly routine task, the full DCMP process had to be adhered to for airworthiness reasons.

18.2.3.3 Investigation of a new paint scheme

To gain an operational advantage, the Squadrons asked the EU to undertake a study to apply a new paint scheme to an aircraft for trials, with a view to applying to the rest of the fleet. Again, a seemingly straightforward request, however, an aircraft's paint scheme is a design-specified feature as it forms part of the corrosion protection strategy for the aircraft. The actual study turned out to be a very involved task, involving substantial material interference investigations to ensure that the aircraft could, in fact, be adequately protected from corrosion with the new style and chemical composition of the proposed paint, whilst also not causing any other adverse chemical reactions between materials.

18.3 Detailed case examples of engineering activities

18.3.1 Different sizes

Much of the above taskings were 'ad hoc' and piecemeal in approach. They were, however, relatively routine – that is, they were to be expected, although not always predictable in terms of scale and schedule.

However, there were other bodies of work that arose because of more systemic issues that threatened the airworthiness or availability of the fleet, and/or presented opportunities for the Solution to find efficiencies and ways of improving effectiveness without extra cost.

The following case examples provide illustrations of the types of more in-depth engineering activity that involved both the Engineering Unit, as well as the Type Design Group.

The rest of this Chapter examines three key issues that arose:

- Canopy cracking
- APU reliability
- Maintenance policy development.

18.4 Canopy cracking

The Milvus, been a 2-seat tandem vehicle, has a closable 'bubble' canopy giving the crew a very wide field of view (a similar canopy design is shown in Figure 57, although is not from Milvus). On this particular aircraft it is partly made from a magnesium alloy. The canopy assembly is far more involved than a static structural system – the actual canopy unit has embedded firing-lines to shatter the glass when the ejector system is activated, prior to exiting the crew through the canopy apertures.

Figure 57: Canopy artifice on a modern military aircraft (Photo: USAF)

18.4.1 Dig a little deeper

These units require a periodic replacement of the firing lines and is performed at the vendor's site in the country of aircraft manufacture. During routine maintenance on one aircraft, the inspection revealed several instances of corrosion on various sections of the canopy frame, some of which were blended out using the existing repair manual instructions. However, some of the corrosion situations had grown beyond repairable parameters authorised within the repair manual, and thus the EU applied to the TDG for advice and a repair scheme to the identified corrosion occurrences.

In addition, while blending out the original 'in-limit' corrosion, the maintenance procedure calls for the application of a substance to indicate the presence of cracks, which in many instances revealed the presence of a relatively large crack in one of the key structural members of the canopy. Further inspections and tests showed even larger cracks than initially identified by the first test.

Concerned by what had been discovered, the EU raised a Special Technical Instruction (STI) to inspect the rest of the fleet. The results were troubling, with only two aircraft to be found not having the episodes of cracking as seen in the initial canopy structure. The Type Design Group undertook a task to provide repair advice for each canopy, as each unit had a unique cracking and corrosion profile. This advice was in the form of how much blending away of the corrosion and cracking could be performed (beyond the approved repair manual) without reducing the thickness of the material in the structure the point of the unit not been able to withstand its load.

18.4.2 Investigating the evidence

Whilst the repair advice was prepared for each canopy, it became important to investigate the cause of the corrosion and cracking in the first place to identify any unknown failure mechanisms, understand if those mechanisms were still at play in the fleet (i.e., an ongoing hazard), and how to fix the issue. As it happened, shortly after the initial cracking problems were found, an aircraft was involved in a bird-strike incident which significantly damaged the canopy structure. As required, the EU undertook an assessment of the canopy to evaluate the extent of the damage to try and determine a repair strategy, with the conclusion that the canopy needed to be returned to the OEM for assessment. The EU & TDG decided that this would be an ideal specimen to examine in closer depth back in the TDG's country-of-origin.

The component was shipped about two months after the bird-strike incident to the canopy's OEM. TDG staff visited the OEM's facility to inspect the canopy, and to perform additional tests on the specimen. Using more specialised equipment, the team determined the presence of yet another (unknown) crack in the structure (albeit smaller than the others). The structure was then broken into smaller sections for analysis, some of which went to the aircraft manufacturer's specialist metallurgical and fractography laboratory (itself a service organisation to the whole of the company, providing specialist and expert advice concerning all metallurgical issues).

Using specialist equipment, laboratory technicians were able to look at the identified cracking and corrosion regions on the structure, as well as perform some destructive strength tests on the material. On both occasions, the material had been degraded sufficiently that they failed one of the material standards test (i.e., the material did reflect the properties that it should have had for its specification on that test, although it did pass on other strength-related tests). After undertaking other tests, inspections, and analysis, the laboratory was able to make some findings concerning the structure, including the likely damage that triggered the corrosion, and subsequent cracking on the structure. Also identified were issues associated with porosity defects throughout the structure.

18.4.3 Considering possibilities

By this stage, the TDG had entered into a phase of considering possible scenarios that would have triggered the corrosion and cracking in the structure, particularly focusing on manufacturing defects, as there was evidence to suggest this found as part of the metallurgical inspection. Particular attention was focused on three areas: a repair weld made during assembly, the presence of a yellowish lacquer along the crack sites, and the potential for an incorrect specification material been used for the structure. As such, the TDG sent a team to the sub-contractor of the OEM (i.e., two-tiers away from the TDG) who manufactured the beam assembly that was the source of the issue. During the visit, the team made seveal discoveries, including:

- A repair-weld made during manufacture, for a while the suspect cause of the corrosion, was, in fact, irrelevant due to the distance between the weld and the corrosion sites.
- A new material flaw detection process had been introduced after the article structure had been built.

In addition, the TDG team asked the frame assembly OEM for a range of information, including radiography reports from manufacture for the aircraft owned by this customer, the original and current engineering processes used for the assembly of the canopy structure, and a cross-referencing of information to determine if any other canopies owned by the customer may have been built at a similar time.

18.4.4 Characterising the problem

Following an analysis of the gathered information, the TDG was able to determine the following:

- That the cracking instances were non-propagating (i.e., aircraft flying operations were not causing the cracks to grow any further), and were likely caused as part of a manufacturing process, although the exact mechanism was not apparent
- The instances of cracking were not a threat to airworthiness and safety, although continued inspection of the fleet at periods specified by the TDG should be conducted to ensure no new cracks or corrosion develops in the canopy structure
- The corrosion exhibited near the fastener holes was likely due to the fastener installation process was stripping protective substances off the canopy frame assembly, exposing them to conditions in which corrosion would occur
- The need for a collaboration between the SDG and the TDG to monitor the corrosion situation to build a more robust and enduring picture about the corrosion issue, including the level and amount of corrosion – detailed analysis done only on this one canopy frame, and as such a more detailed inspection and data-capture of corrosion would help provide this more accurate picture.

Following the investigation, the EU implanted the recommendations from the investigation, including the revised inspection regime, incorporating this into the existing scheme of inspections for the aircraft.

18.5 Auxiliary Power Unit (APU) reliability performance

Another situation the Engineering Unit had to grapple with was an issue with the aircraft's APU. It makes for an informative account of the multi-role aspects of the EU.

18.5.1 The Milvus' APU

The APU on the Milvus was something requested by the NAAF, as previous models only had a more basic engine starter unit. Instead, the APU is installed and used for the following purposes:

- Unassisted main engine start on the ground
- Air-bleed for air-conditioning of the crew compartment and avionics (when engine bleed air not available)
- Electrical power generation (when engine-driven generation not available) – both on the ground, and in the air in emergency situations (to supplement emergency battery)
- Emergency in-flight engine start.

The aircraft was originally fitted with a 'Model 2' APU at aircraft delivery. This Model 2 had superseded Model 1 by incorporating some new thermocouples to protect against water damage. However, after the first few years of operation, it became recognised within the SDG that the APU repair profile was becoming far too expensive, requiring servicing at shorter intervals than was felt was cost effective. Thus, when the APU vendor released a 'Model 10' which incorporated a change to the compressor materials to double the overhaul interval, a retrofit program was launched to update the NAAF's Milvus fleet.

18.5.2 Issues emerge

While the overhaul cost issues on the APU subsided, another problem soon developed – an ongoing spate of uncommanded APU shutdowns across the fleet. These generally would occur during the engine start process, but there were also problems in performing an air-start of the APU.

The trigger for the shutdown in both cases quickly became apparent: in virtually all cases, the fault-log in the APU control system revealed the shutdowns were triggered by an over-temperature detection, triggering a protection protocol whereby the control system would cut fuel to the APU to prevent heat-stressing the APU's machinery. The temperature detection point was at the exhaust (EGT).

Further, it became clear that the ground shutdowns seemed to occur only when the ambient temperature was above 32°C. Conversely, the airborne starts were more an issue of reliability, with the APU starting only about 75% of time when restarted in the qualified envelope (namely under 25,000 feet), rather than the expected 95+%.

Whilst the ground-start situation was an operational nuisance, the in-flight start situation presented a potential hazard: one of the key roles of the APU usage in flight is to provide electrical power to the aircraft if the main engine generator fails, which is essential due to the NAAFs operational profile. The NAAF operate in some relatively isolated areas, with alternate airfields often beyond range of the backup battery's duration.

The issue became significant enough that it was the subject of questioning at a Senate Committee within the New Aragon Parliament. Thus, it was imperative that the APU situation be investigated and rectified to ensure ongoing fleet availability, continual operational safety, as well as to ensure customer satisfaction.

18.5.3 Immediate workarounds

With the issue not abating, action had to be taken by the EU and TDG. However, the investigation had the potential to take some time, and thus interim measures were required. In parallel with the starting of the technical investigation, the EU (with the support of the TDG) initiated some interim workarounds to maintain aircraft availability and airworthiness:

- A revised engine start procedure. The NAAF traditionally started the APU on its own to power-up the airconditioning, plus the avionics on the aircraft, before commencing engine start. The new procedure, however, called for an 'offloaded start' if the temperature was above 32 degrees. This would see the APU started, followed by an immediate engine-start. The aircrew would then activate the generators and airconditioning system, followed by powering up the avionics system.
- A fleet test was ordered by the Engineering Unit to find a more reliable altitude for inflight APU starts. A test conducted on the entire fleet found that the APU would reliably start at 16,000 feet in straight and level flight.

18.5.4 Beginning the investigation

Whilst the mechanism for the shutdown was understood, the exact cause for why the APUs were experiencing an overheating indication was a mystery. Many component changes were made, such as removing the APU control box, to search for a fault in the system; no definitive faults were found, only deepening the mystery. Further, there seemed to be no commonalities between events (such as APU serial number, or 'troublesome units'; shutdowns were random, with the only noticeable commonality the ambient temperature.

The joint EU-TDG investigation sought to consider some of the possible causes to help guide the investigation. As part of this process, it also became apparent that this had not been the first time there had been similar issues with the APU design which warranted a closer look, although there were other possibilities too. Initial considerations included:

- The impact of NAAF start-up procedures whereby the APU was run on the ground for extended periods of time before engine-start whose power demand would 'trip' the APU into a shutdown command.
- Another international customer of the Milvus had reported a similar issue some years ago who operate in similar conditions to the NAAF. In that instance, the TDG determined the shutdowns were actually due to electromagnetic interference: the wiring for the thermocouples that fed back into the APU control box passed through the same loom of wires as wiring to the wing strobe lights. As the strobe lights carried a high voltage in short bursts, electromagnetic pulses caused spurious signals to pass to the control box, triggering an automatic APU shutdown.
- Another customer had another electromagnetic interference issue that caused an APU shutdown. The TDG eventually determined after some months that as the main engine generator came online, the surge of electrical power released down the power wire caused an electromagnetic pulse that interfered with another wire in the same loom. That wire controlled the fuel valve to the APU, which spuriously (and briefly) closed, causing the APU to shut down.
- A potential design flaw with the change in the compressor design. With the Model 2's design, it was built with a shroud-gap (the distance between the blade and the wall of the compressor chamber) larger than the Model 10's due to the material. A prior manufacturing error where the shroud-gap was not embodied on the Model 10 for other customers had led to an overheat situation.

In addition, the investigation team sought information from the APU OEM to better understand the situation. This included historical records of the Model 2 production acceptance testing data – tests performed on units before been dispatched from the factory. Perhaps surprisingly, there was some variability found in the results, including EGT results under certain controlled conditions. As it turned out, there had been some variability in production efforts, including some quality improvements with later serial numbers.

18.5.5 Fault replication testing

Whilst there were several possible causes, it was important for the investigation to try and replicate the shutdown using some controllable parameters. This called for several test campaigns:

- **APU Bench-tests:** This involved selecting an APU to be sent to the OEM on the other side of the world for testing on the production acceptance test-rig. A series of tests were performed to establish a baseline of performance, and comparison to other Model 2 units. This data would become important in the proceeding test campaigns.
- **Aircraft Ground Tests:** Following the bench-tests, the APU was returned to the NAAF, and the SDG reinstalled it back onto the Milvus that had been fitted for flight test instrumentation

purposes. Additional testing equipment was also installed on the aircraft, and a test-plan devised. The plan called for five types of tests (such as mirroring the NAAF's procedures, or basic, 'unloaded' starts), each with their own sub-parameters (such a strobe lights on/off, or access panels open/shut).

- **Aircraft Flight Tests:** Following the ground-test campaign, a series of similar tests were then performed in the air.

The test campaigns were not small events: the flight testing campaign took over five weeks to complete, and the entire testing campaign required a dedicated project manager to coordinate the tests. This included coordinating the various elements of the Engineering Unit and the Type Design Group, including (from the EU) the Flight Systems and the EU Manager, as well as various Engineering and Support Engineering managers in the TDG, the Flight Systems team, the Flight Test team (including instrumentation specialists), plus a dedicated technical representative from the APU OEM. In addition, a wealth of data was obtained from the test recording equipment and was then analysed by the joint investigation team.

18.5.6 Investigation findings

Upon analysing the test data, the joint investigation team was able to pinpoint the principal causes of the over-temperature situation. Interestingly, there were two separate causes for the two different conditions:

- For the **ground case**, when the APU was 'loaded' (driving a generator and air-conditioning pack power requirement), the APU's EGT would rise above the control system's pre-set safe limit, triggering a shutdown. However, the APU installed on the aircraft produced a different EGT value under the same loading conditions as to an APU installed on the production test cell. The difference? The test cell had a straight exhaust duct; the aircraft used a rounded duct, with the thermocouples set a little closer to the turbine outlet, thus causing an 'overheat' alert when the ambient conditions were above 32 degrees, even though there really wasn't an issue.
- For the **air-start case**, the cause was found to be the way the APU control system was designed. The control system demanded a spool acceleration rate that potentially triggered an over-fuelling situation (i.e., to obtain a spool acceleration, more fuel needed to be added, but in this case, the control system released too much fuel), thus causing an overheating situation at the EGT sensor position. Exactly why this issue also manifested when changing to the Model 2 standard was not formally determined, although suspicion did fall upon the material change in the compressor resulting in a not-properly-accounted-for change in inertia.

18.5.7 Making changes

Armed with the results of this investigation, the Engineering Unit and the Type Design Group sought to work with the APU OEM to devise some design changes that would be implemented across the NAAF's Milvus fleet. These included:

- Increasing the 'overheat' temperature setting in the APU control system to accommodate a slightly increased detected temperature to prevent the overheat protection protocol from shutting the APU down.

- Adjusting the APU acceleration programming to drive the APU's spooling at a slower rate to reduce the possibility of over-fuelling.

At the time this study researched this issue, there was still work been done to evaluate and devise these changes.

18.6 Working towards a more efficient maintenance policy

Given the description of the EU's work program in Chapter 15, one could be forgiven its work has been focused on safety-related outcomes only. However, the review of this next project the Engineering Unit engaged in both sought to assure the ongoing airworthiness of the fleet, but rearrange maintenance requirements to reduce the Milvus' maintenance cost profile. It's an example of how the Engineering Unit can also a force for pursuing commercial outcomes, whilst balancing them with technical realities and safety obligations.

18.6.1 In the beginning

The Type Design Group developed the aircraft's original maintenance policy following the creation of a reliability model for the aircraft, based on analytical predictions as well as analysis of years of operational data from other Milvus customers. The results of this analysis, aside from generating the maintenance policy, were delivered to the Engineering Unit and uploaded into a database that held the logistic support analysis record (LSAR) – effectively the aircraft's reliability model.

18.6.2 In-service reliability management

This LSAR was set up to be continually 'refreshed' and updated with real in-service reliability performance in a close-to-time fashion. The LSAR continues to be administrated by both the Engineering Unit in collaboration with the Logistics Unit, sharing a staff of three reliability engineers. This team has a rolling program of assessing reliability, failure and maintenance data coming from various sources around the Integrated Solution community. These sources have included:

- the computerised maintenance management system (which records reliability information of components)
- unscheduled-maintenance arisings
- suggestions and feedback formally recorded from maintainers and other stakeholders.

The team was set up to make formal recommendations for reliability interventions to the Engineering Manager, based on this reliability analysis. These include alterations the Technical Management Plan, generally to make the maintenance policy more restrictive by:

- accounting for systems and components that show poorer than expected performance
- creating new preventative maintenance tasks to reduce the arising rate of unscheduled or corrective maintenance actions that continue to persist. By establishing a preventative task, not

only is safety potentially improved, so too is the cost profile associated with meeting that technical need.

18.6.3 The Milvus' maintenance policy

But what is a maintenance policy?

In this case, it's an inspection and servicing regime broken down according to tasks – specific work packages that contain full detailed steps and procedures to accomplish that particular inspection or servicing. These tasks are called up in the maintenance schedule which dictates when these tasks must be performed; the combination of these two elements makes for the aircraft's maintenance policy. For the Milvus, its maintenance policy was originally made up of 352 separate maintenance tasks that relate to aircraft functionality, with many more that relate to structural health and area inspections.

18.6.4 Enhancing the maintenance policy

About eight years into the Solution's life, the Engineering Unit embarked on an intensive package of work to evaluate and improve the Milvus' maintenance policy to ensure it was still appropriate for the fleet, but also to identify any potential efficiency gains. This process would be highly data-driven, but also involved sound professional judgement, and in this case, a measure of human creativity and ingenuity. However, compared to the regular ongoing process of reliability data-driven maintenance improvements that imposed more restrictive requirements, the intent was to find opportunities to make the maintenance policy more efficient by relaxing certain maintenance requirements where data suggested it is safe to do so. Of course, however, during the review, if some maintenance requirements needed to be made more restrictive, this would be done.

18.6.5 Development strategy & process

Whilst the Engineering Unit has its Certified Engineering Organisation status, it could not just change the aircraft's maintenance policy without some due-process and control. The actual improvement process is defined by the DASR in technical regulations and procedures, although reflects the Reliability-Centred Maintenance (RCM) methodology. This approach uses the normal reliability data analysis activity, but uses it to establish a case for adjusting the magnitude and profile of maintenance tasks, potentially 'pushing out' maintenance schedules.

These adjustments to the maintenance program must first be shown to be safe and that it will still keep the aircraft at an equivalent level of airworthiness. However, the revised schedule and level of work on the aircraft can lead to greater operational flexibilities, reduce maintenance turn-around times, and ultimately lower costs for the maintenance operation.

On a management level, undertaking this project was a substantial undertaking, requiring a project management approach with engineers dedicated to the task to ensure its completion. Such an imposition caused the Engineering Manager to consider one of two approaches:

- a "big-bang" approach, whereby a substantial change to the TMP would be delivered in the one event, or

- through an incremental approach involving a larger number of smaller changes over a longer time period.

In the end, the decision was made to go with a hybrid approach and focus on the maintenance tasks that affected aircraft system functionality, rather than the airframe stucture.

18.6.6 Principles

Further to the mandated RCM process espoused by the regulations, the Engineering team agreed upon six fundamental principles or assumptions that would guide their review process to both make the project more manageable, but also to manage the risk of introducing new hazards to the maintenance policy. These principles were:

- That the existing maintenance policy was airworthy, and that only currently routine, scheduled preventative maintenance tasks would be subjected to the Reliability Centred Maintenance (RCM) approach.
- As such, specialist servicings and extra requirements imposed since commencement-of-operations would not be considered for RCM treatment.
- The major M5 servicing calendar backstop would not be changed. That is, the aircraft must enter an M5 maintenance visit at least every ten years, regardless of hours flown.
- Adopting the maintenance policy of other Milvus operators would not be done, as there were potential, significant differences in configuration, role, and environment. The RCM process would only be applied to the NAAF fleet.
- The RCM process would be applied to functional maintenance tasks only; structural and zonal inspection tasks would be reviewed at a later date.
- The fleet could be assumed to operate at a certain flying rate per year to optimise servicing calculations.

18.6.7 Results

The Engineering team set to work to perform an analysis on each of the 352 tasks to assess their validity and explore any scope for change to the schedule, as well as the actual content of the task itself. Following input from the Type Design Group, what resulted was a more streamlined maintenance policy that introduced some new elements to improve efficiency. In short, the RCM review introduced an 18% reduction in the quantity of scheduled maintenance activity required to maintain the aircraft's reliability and airworthiness.

The process also resulted in some other improvements, too.

18.6.7.1 Improved maintenance policy logic

The streamlining tidied up some inconsistent logic applied to the maintenance policy – in particular, some panel removals were subject to a full task procedure, and others were not, without any clear reasoning or differences between circumstances. The EU worked through a process to tidy up this inconsistency.

18.6.7.2 Revised maintenance policy structure

The streamlining also permitted a slight restructure of the maintenance policy. It now strongly echoes the traditional M1 – M5 servicing blocks described in Chapter 15. However, workload analysis revealed that the M1 and M2 work packages accounted for the bulk of the aircraft's maintenance expense, and a restructure could realise some cost benefits, without compromising reliability or safety.

In particular, the EU identified tasks that could be performed on other occasions aside from the M1 or M2 servicing visits. The optimised approach focused on tasks that could:

- Be completed in a single maintenance shift
- Be completed during unscheduled maintenance
- Be completed alongside other similar tasks or that use similar resources (such as tradesperson skill-sets, tooling or data preparation).

A total of 8 tasks were repackaged as 'independent servicings' that afforded the SDG certain options and flexibilities to complete at more efficient and effective times.

18.7 A unique role

So what can be observed from these examples that increase understanding not only of the discipline but the practice and management of engineering in the in-service environment?

Perhaps most striking is the various dimensions the Engineering Unit must manage. It must handle a significant number of service requests and issues that range from immediate safety matters, through to longer-term commercial or capability related issues. There are different levels of priority, different levels of criticality, a number of various stakeholders, and activities that operate on various time horizons, from literally hours, right through to years and decades.

In addition, the circumstances that dictate priorities are always changing, even on a daily basis. Whether it be the customer's tempo, the SDG's business imperatives (such as contract performance obligations), through to the broader political and military environment that drives much of the priority setting, it presents a complex challenge for the management teams of both the SDG and the Engineering Unit to stay relevant, on-point, and on top of the issues.

These priorities then translate into an actual, dynamic work program, and it falls upon the Engineering Manager to do their bit to coordinate the allocation of tasks, monitor resource allocation to tasks, and ensure that tasks are turned around when required. This is all to be completed while keeping control over the aircraft's configuration and ensuring that the fleet remains in an airworthy condition.

Aside from being a complex area of business, it also makes for an environment that raises the question of what is the true essence of engineering's role and value, and how it can advance its specialist role to the business and the broader Solution environment. It's a question easily parked for academic thought only; however, it's a question the Engineering Unit asked itself – something explored in Chapter 19.

CHAPTER 19

Towards the Future

Case Study 1

19.0 Positioning for the future

The Milvus Solution was originally slated as a 25-year program; however, this does not mean 25 years of the same rigmarole. Thus, this final chapter documents three strategic developments in the life the Complex Integrated Solution and, in particular, the Embedded Engineering Function:

- Changes to the relationship between the Engineering Unit and the Type Design Group
- Internal efforts to remould the engineering management approach
- Efforts to secure the Solution's future in the face of challenges and opportunities.

A core takeaway from this chapter centres on the internal reflection that went on within the Solution Delivery Group about the role of the Engineering unit. It's a reflection that resulted in a subtle, but the very real transformation of the Unit from a conventional in-service support engineering outfit, to something more suited for a service-driven paradigm and makes for an instructive account for repositioning an engineering operation to be a more service and business-savvy one. It also sheds light on some improvements in the way the EU engaged and related to the TDG, areas that were felt to be suboptimal.

19.1 A critical relationship

19.1.1 The Type Design Group & Engineering Unit

The EU has had a strong reliance on the Type Design Group as a provider of specialist expertise and services that can only be sourced from the outfit that designed the aircraft and has access to its extensive records. In this case, as well, the TDG has also been the 'supplier' of a governance structure that extends into the EU to protect the design integrity of the aircraft.

The EU has had a reliance on the TDG for these services for several reasons:

- **Original Design:** The TDG holds original design data for all the aircraft sub-types, manufacturing records, in-service records (where these are provided back to the TDG), test data (including reports, notes, test coupons, and other records).
- **In-service data:** The TDG has a bigger collection of in-service information from across most operators, and can generate a bigger picture as to the health of the global fleet of the aircraft type. It acts as a central hub for several operators to share information and airworthiness data.
- **Expertise:** The critical mass of focus and activity that allows it to host a raft of technical experts on the aircraft, as well as specialist equipment, tooling, and data. Generally speaking, engineering organisations attached to a support operation would not be able to justify employing such a raft of technical specialists on their own, and having these resources centrally available makes more commercial sense.
- **Vendor relationships:** The network which the TDG itself has, including with other units across the company (such as specialist technical services), and relationships with vendors and suppliers for the aircraft.
- **Readied solutions:** A history of previously generated solutions to known problems, in some instances almost in a format ready enough for incorporation into the aircraft (or at least with some minor adjustment to instructions, etc.).
- **Full record:** The EU only has access to limited amounts of information and data about the aircraft and must defer to original design data to make a determination on given issues, hence relying on the TDG. This also extends to accessing the wealth of expertise and specialist know-how that the EU could not justify hosting itself.

19.2 Relationship management

19.2.1 Areas ripe for improvement

However, despite the significance of the reliance, the EU had identified some areas of improvement regarding the substance of the partnership, as well as the service it received from the TDG. These included:

- Performance and turn-around time issues
- Reduced levels of flexibility
- Management of expectations concerning prioritisation and when responses to queries and requests might be received
- Misjudging the nature of the Integrated Solution and the contract deliverables
- Misalignment between goals of the SDG and the TDG
- Diminishing capability.

19.2.2 Performance & support effectiveness

The SDG Engineering Unit team reflected on concerns regarding the performance of the Type Design Group when responding to queries, requests and identified needs of the EU.

For example, one instance where a manufacturing defect had been identified, which precipitated a fleet-wide grounding for some weeks, was referred to the TDG for advice and for both an interim and long-term solution to be found. Based on the nature of the contract, the SDG incurs liquidated damages for each airplane not delivered every day below the 28 minima. In this instance, the grounding cost in the order of millions in foregone revenue. However, the response from the TDG was characterised, by the EU, as being slow and unresponsive. It took some weeks for the TDG to come back with an answer that would allow the fleet to resume flying operations.

When the EU tried to convey a sense of urgency about the situation, a level of pushback was felt by the EU, with the team been told to wait for the report by the engineering team at the TDG. This formed a view within the EU leadership that the TDG was devising a “gold-plated” solution, rather than a safe but quick workaround in the interim, and ultimately an eventual rectification of the technical issue.

19.2.3 Managing expectations

The Engineering team also expressed concerns regarding the management of expectations and the communication of task performance. The TDG deals with several client operators, and with the SDG responsible for one of the smaller fleets, does not always get priority on tasks – a situation the EU is empathic towards. However, when the EU would query when they might expect to receive a response on an issue, or receive some other form of information that could help the EU plan how it would work around a technical situation, a response was sporadic. As part of a plan to reorganise the EU for future success, this became a critical management issue.

19.2.4 Delivering value

Adding to the concern was that the EU pre-purchases a set of workhours from the TDG on an annual basis. However, the feeling was that these were not delivered as contracted, an issue exacerbated by the intra-company nature of the contract and the lack of leverage due to the pre-purchasing arrangement. Also, how work hours were expended was not always clear, with the TDG using some these pre-paid hours to recover information that was already in the possession of the TDG, an activity not felt to be value-for-money. This included having to pay for ‘standard’ repair schemes (fixes previously generated for previous problems on the aircraft), despite the fact most, if not all, the engineering effort required to develop the fix had already been expended when the issue first appeared.

19.2.5 Goal misalignment

The Engineering team also expressed a sense that the TDG exhibited strong technical expertise, but that such a ‘heavy engineering’ approach was not always what’s needed. This leads to a mismatch between the goals of the conventional product-centric TDG, and the goals of the service-focused EU.

Traditionally, the TDG has been highly design-focused – that is, it has organised itself around design projects where new aircraft or major upgrades form the output of the TDG’s activities, following a systems-engineering approach. As the Milvus design began to enter into the twilight years of its life-of-type, new product development work is tending to decrease; thus, TDG leadership has focused more on in-service engineering work. However, when new design work emerges, there is a natural attraction towards product development-style work to the point of a partial neglect of the in-service engineering support effort.

For an in-service entity such as the EU, this can lead to in-service engineering tasks been treated with less priority or focus. Even with a long-term decrease in new design-type work, there was an impression that the new product development mindset has been translating across into the in-service engineering space. This was manifested in a number of ways, including an emphasis by the TDG on devising 'gold-plated' solutions, applying new-product development work practises (such as devising large design reports, and following product-orientated procedures that are designed to be robust, but are also inherently inflexible), and organising around discipline-based teams (e.g., structures, dynamics & loads), rather than been focused on customer operations. There has also been a view within the EU that the TDG leans towards technical analysis rather than dynamic solution-finding – that is, more concerned with deep scientific and technical matters to the neglect of finding simple and safe workarounds that fix customer problems.

19.2.6 The lifecycle of a Type Design Group

A factor explaining this goal misalignment was the fact the TDG engages with close to a dozen different military customers who themselves are engaged in a spectrum of activities, ranging from acquisition decision making, through to pure sustainment. In other words, responding to matters that span the whole traditional product lifecycle.

At the conception of the aircraft, the TDG would have had complete focus on acquisition and design; however, even as the original type was entering service, it would have begun, by necessity, alter its focus from design to manufacturing and in-service support. In this case, the original aircraft was followed up with an upgrade, and shortly after that, released an updated version of the Milvus for foreign customers, this requiring the TDG to balance design, manufacturing and sustainment activities across more than the one customer.

As time went on, the TDG would have experienced several different emphases throughout the life of the organisation. These different emphases would have driven a different staffing profile during these periods, with a group of staff focused on sustainment, with another group focused on acquisition/design. This 'toing and froing' was illustrated by two of the SDG Engineering leadership team as 'resource balloons'.

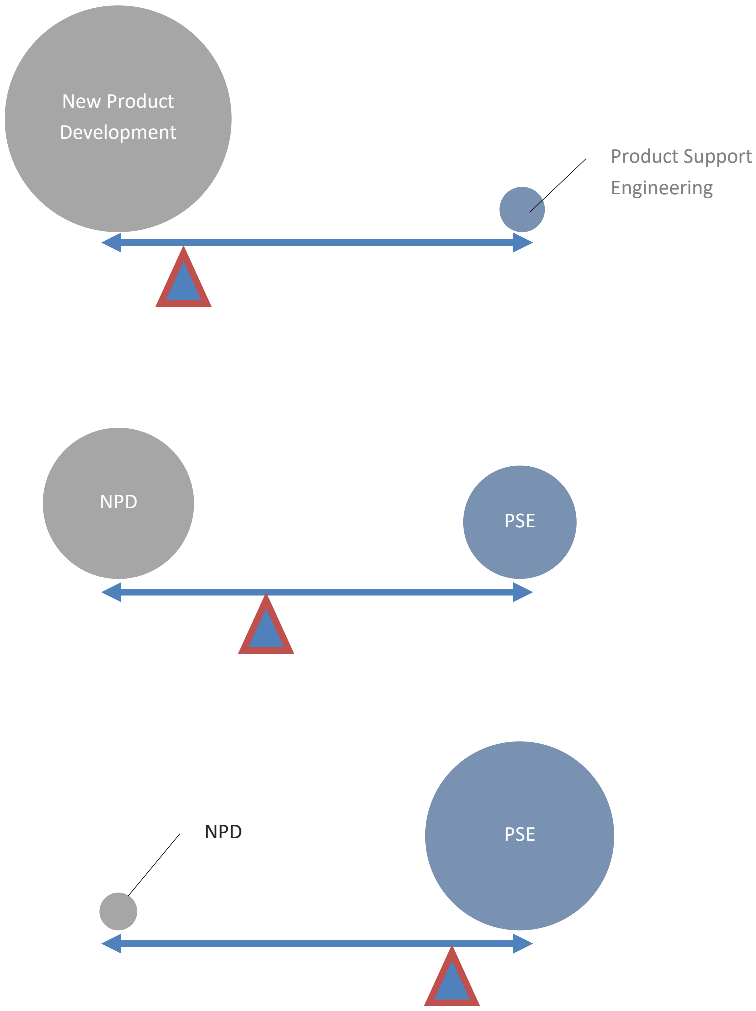

Figure 58: Time-displacement of the TDG resource gravity profile. Fully understanding this phenomenon would make for an entire study in its own right.

Not only was there a balancing effort required in resourcing (driven by customer demand), but the difference in the cognitive activity (e.g., the types of problems to be solved) would have provided an additional management challenge. As noted above, the engineering workforce being very design-orientated would have made the coordinating of resources between different parts of the product lifecycle, and different customers, an additional complex issue to navigate.

The two managers used this historical perspective to explain the current challenges faced by the TDG and how it sought to manage its operations. The challenge of managing a fluid-like organisation comes down to the aircraft's Chief Engineer – making sure that all engineering tasks, whether new-design, build, or support, are appropriately resourced with skilled, experienced, and competent staff, and that the engineering 'product' are of a high standard.

19.2.7 TDG capability & sustainability

During the research, the manufacturing effort on the Milvus continued to gradually wind down, which raised questions within the SDG regarding the loss of technical capability of the Type Design Group.

19.2.7.1 Loss of capability

The TDG had experienced several tranches of job layoffs over the past two decades, and with production thinning out, some engineering teams began to thin out too, often seeing decades of engineering experience been lost. The EU Engineering Manager commented on how this reduction in the capability of the TDG has already become manifest, with queries and taskings taking longer to process, with the quality of some responses having being questioned. Going deeper on this issue, the SDG expressed concern about the possibility of the complete loss of the Type Design Group as it stood, with its responsibilities moved away from the existing team structure and placed within a generic part of the Military Aircraft Division in Essenheim.

19.2.7.2 Potential major disruption

One of the expressed concerns was that the TDG had in fact been moved once before when manufacturing operations were relocated and where few of the original engineering team had transferred to the new location. This resultd in a significant loss in capability; by one account, it took eight years to rebuild the previously held capability. Even though most of the records had been relocated, the loss of tacit knowledge regarding the history and functionality of the design of the aircraft had become a very tangible problem. Armed with this historical knowledge, the SDG expressed concerns over the longer-term issues associated with any proposal for the subsuming of the TDG.

19.3 A natural collaboration

19.3.1 Finding a new partnership model

However, regardless of the expressed concerns with the TDG, a strong relationship between the Type Design Group and the Embedded Engineering Function of the Solution has proved to be a mutually beneficial relationship.

As DefTech Global's corporate strategy includes a thrust into the sustainment market, it makes for an interesting test-case for melding a new corporate structure and way of doing business, especially given that the SDG and the TDG are part of the same enterprise. This includes how parts of the company work together (whether by design or by default) to achieve a sensible, coherent and efficient partnership that works for the company, its shareholders and its customers.

It didn't start out this way as the previous section alludes to, with the TDG acting as 'master'. However, as the SDG's needs have repeatedly bristled up against the status quo of the TDG, it has prompted actions on both the part of the EU and TDG to find a better way of working together and take advantage of the very complementary nature of the two organisational units.

These arrangements, revised in only in more recent times, have led to a more collaborative relationship between the two entities, and closer to an optimum situation from the perspective of the EU

Engineering Manager. During a workshop, the Engineering Manager expressed the need for a localised Engineering Unit, as well as a broader and more in-depth Type Design Group.

19.3.2 From master to partner

In the early years of the Solution, DefTech Global's technical policy was that only one unit across the entire company could hold a product governance authority, and as such the Engineering Unit did not receive an internal corporate authority to make changes to the Milvus aircraft (even though the NAAF regulations could have permitted it). As such, the strict regime of internal delegations and authorisations added an extra layer of complexity to the Engineering Unit's operations. Even when the EU had a validated solution to a problem (that required a design change or deviation), the EU did not have the necessary autonomy to execute that solution without the TDG's approval.

In the words of the Engineering Manager, this meant that the SDG 'could not control their own destiny' and were presented with a challenge where the TDG was both a master, as well as a supplier. It was this particular point that motivated the SDG to engage in a campaign of proving its growing capability and technical proficiency, showing that not only was it an effective localised, tactical engineering outfit, but it had the wherewithal to be a trusted partner in taking on more and more technical authority for its own fleet.

As the EU moved from being an incumbent engineering outfit to a more mature technical agency, the way the EU and the TDG engaged with one another slowly changed. Initially, interactions were characterised as being that of a "big brother" approach, with almost all queries characterised as "can we do [task/modification/change]" with a high level of dependence. After a while, the relationship morphed into what has been described as a "support act", with a bigger emphasis on asking "these are our intentions – any input or issues." The relationship has progressed even further with a greater level of recognition, two-way interaction, and equal footing.

The SDG's efforts have been paying off. The governance framework covering the TDG now extends to the EU, so that the Engineering Unit's Manager and his team are now recognised as 'part of the TDG family', meaning that many of the EU's actions are recognised as effectively coming from the TDG, even though they are different and independent organisations.

19.3.3 A bestowed recognition

Following a review of the governance frameworks and internal authority bestowed by the Type Design Group, the Engineering Manager within the Integrated Solution was recognised with an internal company designation as a Weapon System Integrator (WSI). This is an internal company recognition of an engineering professional/leader when their role has significant coverage (i.e., more than two disciplines) across an entire aircraft, and the individual is required to bring together the actions, work, and decisions of several different sub-teams.

Within the TDG, each of the customer desk managers were also recognised as WSI's for the fact that they must coordinate and bring together several different engineering tasks and activities to satisfy a customer's need and to present a single interface of the TDG function to the customer organisation. So, for the EU Manager to receive this title again reaffirmed a sense of being part of the Type Design Group's inner circle.

19.3.4 A voice at the table

This partnership approach has also been reflected in the forums in which now the EU and TDG contribute as equals, rather than unequal capacities. These include:

- EU involvement in the monthly TDG Chief Engineer's review meeting at which the EU can share information as a mutual partner, often an opportunity for the TDG to hear specific details of technical issues 'from the field' before other customers raise them.
- A permanent invitation for the TDG Chief Engineer to join NAAF's annual Airworthiness Board that oversees the Milvus.
- Ongoing fortnightly conference calls between the EU and the TDG for issues specific to the SDG.

19.3.5 More valuable when working together

19.3.5.1 The Engineering Unit benefits

Clearly, the EU gains in a closer relationship with the TDG by having access to the very deep and specialised expertise that helps it in its persistent operational service and support efforts. The TDG brings concentrated expertise to solve problems-of-depth, issues that are not routine and require both deep domain knowledge, and access to a wealth of design and historical record data. The TDG is also ideally placed to create a global picture of the health of the aircraft product, something an EU by default only sees a part picture of. It's a capability that is expensive to maintain for a fleet of 33 aircraft – thus a centralised pillar of expertise and assistance helps reduce costs for both the SDG, but also other customers.

19.3.5.2 The Type Design Group benefits

However, when working together, the EU also helps the TDG become a more valuable epicentre for the broader Company. Close collaboration provides the TDG with a strongly aligned and motivated partner who is both also 'in the tent' (for sharing proprietary information) but also continually at the 'coalface' of supporting the aircraft, with all that has to offer. This includes:

- Critical and tailored information about the performance of the aircraft, including reliability and safety issues,
- further data about identified problems,
- alternative 'field-derived' solutions for technical problems, and
- information about the true cost of operating and sustaining the aircraft.

19.3.5.3 The whole Company wins

This partnership already has delivered significant benefits for the Company. When bidding for a major Milvus export deal, the TDG reached out to the EU on several occasions for lifecycle costing information to better price proposals. This helped DefTech Global to secure one of the biggest export orders for the Milvus in the history of the program.

19.4 Re-organising for ongoing success

After almost a decade of actually operating the Solution, the Engineering Unit went through a period of consolidation and reorganising. This period was triggered by several factors, including:

- challenges in managing the broad range of activities into which the EU was asked to participate in (beyond what was normally expected of a technical unit),
- challenges in retaining focus on tasks-with-depth such as the maintenance policy review,
- developments with the Type Design Group, and
- a crystallisation within the EU team of the true role of the engineering function within an Integrated Solution environment.

This led to a re-evaluation of the structure and role of the engineering function within the bounds of the existing regulatory regime, with a significant reorganising of the Unit’s structure, task management approach, and its value proposition to the SDG, the NAAF, and others.

19.4.1 An internal observation

From the launch of the Integrated Solution, the EU had sought to solve issues through traditional discipline structures. The EU’s team structure of about 22 staff was organised along functional lines, including Structures, Flight Systems, Avionics, Reliability Engineering, Configuration and Data Management, and Training Aids Engineering. The Engineering Manager would allocate tasks to each team based on the nature of the issue (e.g., an avionics issue would delegated to the avionics team).

However, the Engineering Manager had observed over time that several tasks were not strictly driven along discipline lines and involved a level of overlap between the various technical disciplines. In addition, there was a lack of conscious distinction between tasks with an airworthiness bent those more contract obligation-driven (with several matters a bit of both). Further, while urgent operational issues took up much of the Unit’s attention bandwidth, longer-term tasks and projects, many of which could improve the effectiveness and efficiency of the Integrated Solution, weren’t getting the attention they needed.

19.5 Reshaping the Engineering Unit

19.5.1 Change to the Engineering Unit’s structure

To create a greater level of visibility, accountability and prioritisation, the Engineering function was restructured to become a line-of-delivery-based organisation using multidisciplinary teams. Each area of delivery had a new team-leader appointed, and each team had different metrics most suited to that particular focus. The same engineering team head-count was still present, but the personnel was re-allocated to each of these teams, with some flexibility for moving around as workload dictated.

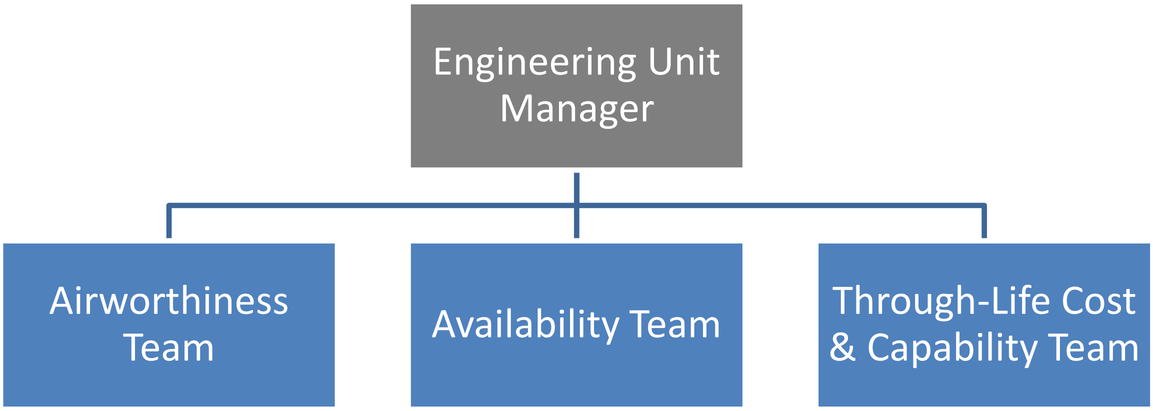

Figure 59: New Engineering Unit management structure

After much internal thought, the SDG leadership team identified that the key technical management lines of delivery existed along three lines:

- **Airworthiness:** to provide a very clear oversight of airworthiness issues and provide actions and responses to taskings that had a very clear airworthiness concern attached to them which, if not addressed, could present itself as a hazard. This team has become mainly involved in the management of Special Technical Instructions for the fleet.
- **Availability:** to deal with issues that were more routine in nature, but which would affect the availability of the aircraft. This dynamic team is structured to focus on providing quick solutions to problems that would otherwise keep the aircraft on the ground, including non-design workarounds (such as authorising part-swapping), as well as identify more longer-term reliability issues that affect the ability of the SDG to perform on availability metrics.
- **Through-Life Cost and Capability:** focused on longer-term issues or projects associated with increasing the capability of the Milvus, or managing the costs associated with the Integrated Solution. The large maintenance policy review project fell under this purview and was transitioned into the TLCC team until its completion.

19.5.2 Change to the management of workflow

The shakeup of the Engineering Unit was not just in structure. A new approach to managing workflow accompanied the restructure to ensure that there was a wholesale change to the way the Unit approached its responsibilities and expectations, and not a 'half-baked' structure change. By separating technical issues according to their actual need (i.e., airworthiness, availability, and cost/capability), it gave the EU a much clearer insight into the drivers of tasks and drove a higher level of accountability for ensuring that tasks were completed promptly, based upon their actual importance.

Tasks generally come from two sources, either the formal Technical Information stream or through dialogue with the customer (either the Squadrons or DCMA). Tasks are provided with an initial review, then priority-ranked by the team leaders for the nature of the task (e.g., availability), and then recorded and tracked through the existing IT tool. Metrics appropriate to that line-of-delivery were also put in place to monitor team performance.

19.5.2.1 Airworthiness

The Airworthiness team carry out the same responsibility for safety as before the change, albeit in a slightly different way. It has responsibility over about three-quarters of the TI that comes in. Metrics for airworthiness were more of a challenge, as (ideally) the target is for no catastrophic or hazardous events. As such, a series of process-based metrics have been introduced, including the backlog of issues, and time taken to issue airworthiness instructions such as STIs.

19.5.2.2 Availability

The Availability team responds to about a quarter of the Technical Information that comes into the EU. It has a reasonably straight-forward manner of monitoring performance on tasks that need actioning, by setting a due date, followed by a performance result following task-closure, falling into three categories:

- Delivered on-time
- Not delivered on-time, but a workaround was able to prevent an 'availability-bust'
- Not delivered on-time, and led to one or more aircraft not been available for service.

19.5.2.3 Through Life Cost and Capability

Devising metrics around the Through Life Cost and Capability team were more relatively straight forward, but the nature of this team also introduced other challenges.

The team was established primarily to address the "can you just" type requests from the customer that previously had entered the EU's jurisdiction without devoted attention. Where much of the taskings for the Airworthiness and Availability teams would be raised from reporting or formal disposition requests (as per the management system), the TLCC team was set up to respond more proactively to stakeholder needs. These often included feasibility studies, installation of new equipment, modifications, or enhanced operational clearances (such as operating with lower tyre pressures for better airfield performance).

This enhanced level of engagement primarily fell on the TLCC team-leader who was made responsible for spending time with the customer to establish current and projected development needs and to better understand their drivers. A process was developed whereby potential needs were scoped with an estimated resource requirement and the impact on other projects already in progress. This would then be presented back to the customer, enabling an informed negotiation and prioritisation for the new prospective project. In some instances, this process helped narrow down the actual problem to be solved, or in some cases completely stopped an ultimately unnecessary body of work from happening.

Following customer agreement, a more formalised approach would be adopted. As most of these tasks were beyond the existing scope of the Integrated Solution contract, a formal survey and quote activity would be performed to provide a cost estimate to the customer to establish a side-contract to undertake the work. Also, regardless of contract mechanism, a "Plan in a Page" would then be developed, where the objectives, task description, timeframe, and metrics are expressed and becomes an explicit agreement between the EU, the customer, and quite often the TDG who would perform many of the tasks. The list of open tasks were reviewed and re-prioritised on a periodic basis to ensure progress and effective resource allocation. Changes could be made, but only at this regular review juncture, so as to provide some discipline around the executing of work.

19.5.3 The effect

One of the major issues that the EU had faced since it commenced operations was how it handled such a persistent and broad set of requests, demands and problems. The Engineering Manager described the experience of oscillation, or "changing channels" on an ongoing basis, bouncing between urgent operational issues and important, longer-term matters. This continual shifting of priorities was making it almost impossible to achieve what the customer requested and meant that the EU was constantly playing 'catch-up', especially given the fixed engineering resource at hand.

The cut across to the new structure put the EU back on the front-foot. Instead of been driven by the constantly changing priorities of different facets of the operation and the customer, the EU now positioned itself in a proactive manner and has meant a more streamlined, efficient and focused provision of technical services throughout the SDG and to the customer organisation. In doing so, it has also been able to demonstrate critical organisational behaviours that it had struggled with: consistency and certainty of delivery.

19.6 Reframing the role of the engineering unit

Concurrent with the campaigns to forge a closer partnership with the Type Design Group, as well as reshape the Engineering Unit, was some internal 'soul-searching' as to the role the Unit pursued.

19.6.1 A refocused part to play

The granting of the Weapon System Integrator status coincided with a gradual transition of the Engineering Manager's role from that of a strict technical expert, to something that he described as "more of a project manager". While ultimately responsible for the airworthiness of the fleet, this was increasingly discharged through the engineering team, with the executing of technical issues now been the responsibility of team leads. Since this process began, the Engineering Manger's role became "more strategic" and more "attuned to business needs".

In particular, the Engineering Manger motioned that his role was becoming "how to best shape the resources of the Engineering Unit to meet the needs of the (Integrated Solution)". The role increasingly became one of influencing the SDG to make better use of the engineering resource. Whilst the EU did not 'own' the Integrated Solution[25], it did exert significant influence over the Solution, providing a

[25] Strategic issues such as contract changes remained the responsibility of the Project Manager and ultimately the SDG Director

unique 'empowering' contribution to help the SDG perform, and was the chief adjudicator between competing and conflicting objectives that the Integrated Solution engendered (such as safety and availability).

One expression of this is how the Engineering Unit actuated its engineering nous. Although the Engineering Unit was made up professional engineers, it was not just engineering-based solutions that it sought to apply to the daily raft of challenges, such as redesigns or modifications. Rather, the engineering team were cognisant of the resources available throughout the entire SDG (and often beyond) to find the best solution for the given circumstance, and it often involved fixing a technical issue with a maintenance or logistics solution, even if just in the interim. It was not just applying conventional engineering techniques, but using some of the higher-order engineering competencies that helped the Unit provide value.

As such, the Engineering Unit has become seen as the primary problem-solving agency of the SDG. While it does not dictate service delivery program management, it both played a defining (and occasionally directive) role in their success, but also helped solve many of the non-routine technical problems encountered by the Solution.

19.7 Securing the Solution's future

As a way of drawing this case study to a close, it's both instructive and contextually useful to consider some of the future opportunities and challenges that face the Complex Integrated Solution, and what this might mean for both the customer and the Solution Delivery Group.

There are four key areas:

- The looming threat of customer reforms and its impact on the Solution
- The prospect of a major upgrade program for the Milvus fleet
- Securing the next phases of the in-service support contract
- Considerations for retiring the Milvus and transitioning to the next-generation solution for fast-jet training.

19.7.1 Defence reforms

The entire Integrated Solution does face a pressing challenge on the financial front. While the customer enterprise's budget (i.e., the Defence Budget) has, for the whole, been growing for many years, there has been significant pressure for some years on making that finite budget stretch further. Broader political and economic circumstances within New Aragon and more globally mean that expenditures are under closer scrutiny, and as such, Defence reform programs have been created to identify savings and ways of rearranging the force structure to produce greater economies.

These pressures could potentially feed down into the architecture of the Integrated Solution, including the possibility of reducing the target number of flying hours and thus attempt to reduce the costs associated with the support of the aircraft. Other customer-driven efforts to make NAAF maintenance operations more 'lean' to secure cost savings are also looming as a threat to the SDG's profit margin and autonomy of action. These reforms may also impose some delays or strictures on plans for a proposed mid-life upgrade.

19.7.2 Securing next phases of the contract

There is no guarantee that DefTech New Aragon will retain the contract for the life of the Milvus aircraft as the in-service support contract is renewed every five years. Thus, the SDG must undertake efforts to ensure subsequent phases of the program are renewed under favourable terms.

A previous contract phase renewal did see some changes to the contract. The first change clarified some of the performance requirements set on the SDG and introduced a more ‘graduated’ approach to performance (as illustrated in Chapter 13). As such, the recontracting period offers an opportunity for the customer and the Solution provider to introduce new initiatives, concepts and expectations to enhance the Solution. Invariably, it’s also an opportunity for the provider to put forward justification for a fee increase, while the customer may use it as leverage to obtain a lower price. Either way, the Solution provider does need to put forward the case why it still offers value and will continue to be a more valuable contributor to the NAAF over its competitors.

It’s also an opportunity to reshape some of the fundamentals of the Solution. This is perhaps seen in recent efforts that have focused on seeking to expand the scope of the Solution to encompass some of the line maintenance activities of the operational Squadrons to deliver a truly comprehensive fleet management Solution that delivers a capability and not just readied assets. Such a change would require further coordination and management efforts on the part of the SDG’s leadership team to deliver a Solution which does far more, including loading weapons, refuelling the aircraft, and strapping in the pilots.

19.7.3 Programmed upgrade to the Milvus fleet

From the very outset, the NAAF had planned (and budgeted) a mid-life upgrade exercise to ensure that its aircraft maintained its ability to give it the training edge. The plan was to enhance the Milvus’ capabilities and to reconfigure many of the pilot interfaces and weapon systems to mimic a fifth-generation fighter aircraft the New Aragon Government was considering acquiring.

At the time of the research, the SDG was examining options to present to the NAAF potential upgrade options. These included new systems to be adopted, cost estimates, and proposals to ensure a minimally interrupted flying program while the fleet was updated*.

[* For example, a ‘spiral’ upgrade to build the aircraft up to a new standard over a series of maintenance or modification visits, rather than a ‘big bang’ approach.]

A major upgrade will represent a significant exercise, one that will require close collaboration with the Type Design Group who will likely perform the product development and design work, with the embodiment coordination most likely carried out by the SDG. Furthermore, it represents a challenge for the SDG to ensure it doesn’t drop the ball in its regular operational performance whilst also ensuring a step-change in capability for the NAAF.

19.7.4 Retirement, replacement or rejuvenation?

There was also early movement within the customer to start thinking about replacement options for the Milvus. While the anticipated withdrawal date of the aircraft fleet is 2025, the customer tends to stand up a project team about ten years out to ensure there is minimal loss of capability in a future transition scenario. Part of this thinking is around analysing results from fatigue life tests on the bare aircraft frame brought as part of the acquisition process to see if there is any scope to extend the life of the Milvus. This may also involve another major system upgrade to keep the aircraft's mission capability up-to-date.

If such a pathway were to be taken, then there are implications for the SDG:

- The need to negotiate contractual change to account for the added expenses of sustaining an aged airframe, potentially reducing some of the performance-based measures given the bathtub effects on its reliability
- Potentially growing the size of the organisation to account for more maintenance and engineering work to meet the increased demand due to the aircraft's age
- Undertake a detailed study to understand likely obsolescence scenarios and put in place alternative (such as bulk part orders or sourcing a new production partner).

Of course, if the NAAF decide to go with a new-build aircraft, DefTech will likely seek to be involved, whether it's by:

- Promoting a new generation version of the Milvus (if it remains in production by this stage)
- Acting as a Solution Integrator by proposing to deliver a service similar to the one it currently provides, but with an aircraft of another design from another manufacturer.

Either way, the end-of-life scenario is one that requires careful management as the NAAF embarks on transitioning to a next-generation fleet and one that DefTech Global will want to put forward its credentials as a reputable and reliable partner for the future.

19.8 What can be learned from this case study?

Much of the narrative of this case study is around the development of the Solution from the outset, as well as the early years, and into a tentative maturity of the Solution's operations. While the rest of this study is devoted to extracting understanding from the case studies, it's helpful to conclude the detailing of this unfolding account by recapping some of the major stand-out points from this sizeable case example.

19.8.1 Structured for output-vs-outcome

DefTech subtly took an approach where they were building an output organisation, predicated on a production-style model. That is, an organisation that was established to 'push-out' and deliver 'things' (namely aircraft) according to a pre-agreed timeline or specification. However, as the Solution operation matured, it became apparent that was needed was an operation that could support a *customer*, not just a product.

In previous programs, the contractor is merely directed to execute a package of work according to pre-set standards. In this instance, both DefTech, as well as the NAAF had to rework this traditional practice, and instead collaborate. Also, DefTech came to realise that its operation needed to adopt a different operating model, one accustomed to a more dynamic, variable and not always predictable demand by the customer (see Figure 60). Those demands would be on several fronts, and not always with a clear demand signal (e.g., sometimes an inherent Squadron expectation around when a particular aircraft was needed back on the line, rather than a formal service request).

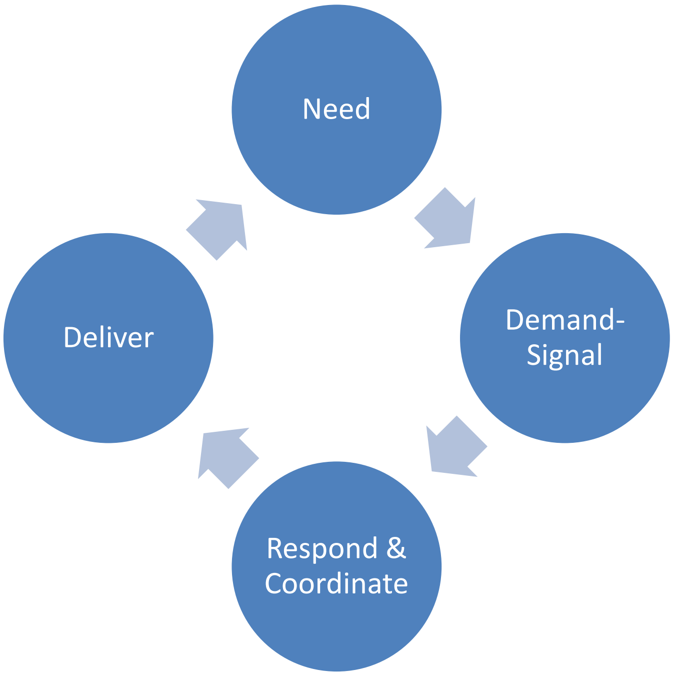

Figure 60: Meeting dynamic needs, and not just pre-programmed outputs

19.8.2 Rediscovering engineering

Another major lesson from this case study was the internal deliberations about the role of professional engineering in this context. While this also focused on finding a balance between a centrally-controlled product governance structure, and a highly flexible and adaptable Embedded Engineering Function for a client operator, discovering a new form and expression of the EU was a major learning point. That engineering is not just a product-centric endeavour, but that is something more that involves engaging with stakeholders and operating in a more proactive manner, is a major theme that this study seeks to build upon.

CHAPTER 20

The EmeraldJet Airlines' Fleet Management Group

Case Study 2

20.0 New school airline, old school engineering

Case Study 1 was an extensive examination of a Complex Integrated Solution for a military customer involving a frontline jet trainer aircraft. However, this case study now turns to looking at Solutions in the context of a modern airline.

As touched on in Chapter 2, most prominent availability-based Solution concepts exist in the military domain, and what commercial airline examples can be found are generally more a piece of an integrated approach (e.g., Power-By-The-Hour with Rolls Royce, or outsourced maintenance activity, which is not the same as the full fleet management function). Hence, this case study is not of an outsourced availability Solution; in fact, it's quite the reverse. It's the account of an internal airline engineering and maintenance outfit discovering that it was their prerogative to be a Complex Integrated Solution to the broader airline company, and thus structure themselves accordingly.

This case study examines the Fleet Management Group (FMG) of *EmeraldJet Airlines*, a pseudonym of a leading low-cost airline carrier known for its flamboyant brand image and customer-focused culture. The FMG, whilst structured as a division of the airline, was operated more like a supplier (or a contracted provider) to ensure the availability of the airline's fleet to meet airline schedules. At the point of the investigation, the FMG was responsible for a fleet of approximately 60 aircraft of two FAR25 jet-types.

However, it's not just a description of the responsibilities, functions, and routines of the FMG. Rather, it also delves into a change management endeavour undertaken by the airline to rethink the Fleet Management Group and how it positioned itself. It's a fascinating account of an 'old-school engineering outfit' transforming into a 'new school operation,' in turn revealing some of the nuances of operating an airline fleet management Solution.

20.0.1 Looking for engineering

It's important to note the context and makeup of this case study are different to the first one.

First, the Milvus Solution was a fully contained availability Solution, with DefTech performing most of the noetic and hands-on work for the upkeep of the fleet (namely engineering, logistics, and maintenance). In this case study, EmeraldJet's FMG is more of an integrator – much of its maintenance activity is outsourced, and even some of the noetic activities, too, are outsourced to other providers, including professional engineering services.

Second, drawing a line around the team of professional engineers (i.e., the EEF) is less straightforward in an airline environment, with much of 'Engineering & Maintenance' actually referring to the trade concept, rather than the professional definition. The airline environment tends to meld the maintenance planning, fleet management, logistics management and engineering support functions into a more activity-based work-structure; in other words, mixing tradespeople, professional engineers, and other professionals into task or service groups, as opposed to disciplines or professional tracks. However, the Fleet Management Group is made up of professional engineers working in various professional capacities, and this is pointed out during the portrayal.

Following on from this second point is that finding the Embedded Engineering Function is a little more involved. In the previous case study, the Embedded Engineering Function was a clearly identified unit of predominately professional engineers within an organisational unit devoted to running a Solution. In this case study, it's a more distributed concept, although the Technical Services Unit is about as close to a professional engineering section that can be seen in this case study.

Fourth, this case study is less specific in its focus on the Embedded Engineering Function; however, explaining the inner workings of the airline's Fleet Management Group does highly contextualise the distinct role of the EEF and the value that it offers.

20.1 EmeraldJet Airlines

20.1.1 Company description & developments

EmeraldJet Airlines commenced operations in the early 2000s and has grown to become a major carrier in its home market. At the time of this investigation, EmeraldJet Airlines:

- Operated approximately 60 aircraft of two narrowbody type jet aircraft (most of the fleet is under a leasing arrangement with various aircraft finance corporations)
- Ran primarily domestic routes, although offered a limited number of short-haul international sectors
- Operated a network of 30-40 destinations
- Had carried in the prior 12 months approximately 16 million passengers
- Employed approximately 5000 staff.

The airline's brand espoused being a high-energy, customer-focused, entrepreneurial, leisure operator, operating to a low-cost carrier model, but with a focus on a fun-loving customer service culture. For the first few years, the airline had only operated the one aircraft type in-line with a 'traditional' low-cost carrier ethos that costs could be minimised by only operating one type of aircraft, saving on spares, avoiding duplication, and increasing efficiency.

Figure 61: EmeraldJet Airlines logo

However, some years before studying this case, EmeraldJet set an altered course for the company, moving away from a strict low-cost carrier model, and instead seeking ways to secure higher yielding business travellers. It started adopting some of the services found at premium carriers where it made more sense (and money) to provide such an in-flight and on-ground product over maintaining the traditional low-cost product, while still maintaining the unique, cheerful brand image. As part of that strategy, the airline opted to order another, slightly smaller jet aircraft type for use on more thinner routes where the larger narrow-body jet was too big.

EmeraldJet's corporate headquarters was established in the CBD of its home port, with its Operations Control Centre (OCC) located at the home airport, with its 'Engineering Operations' (which this study will refer to as the Fleet Management Group) based on the other side of the main runways of that airport.

20.1.2 Airline operations and the OCC

Airlines are made up of many divisions, including flight operations, training, customer service, airports and sales. For this case study, the unit of analysis[26] is the Engineering Operations group (referred to as the *Fleet Management Group*, or *FMG*) which forms part of the Operations Division. This group formed an integral component of the airline (i.e., it was a part of the overall corporate structure of the airline business).

[26] Further refining of the unit of analysis is done later as the 'Engineering Operations' group is an 'engineering community' – made up of trades persons, logisticians, as well as professional engineers

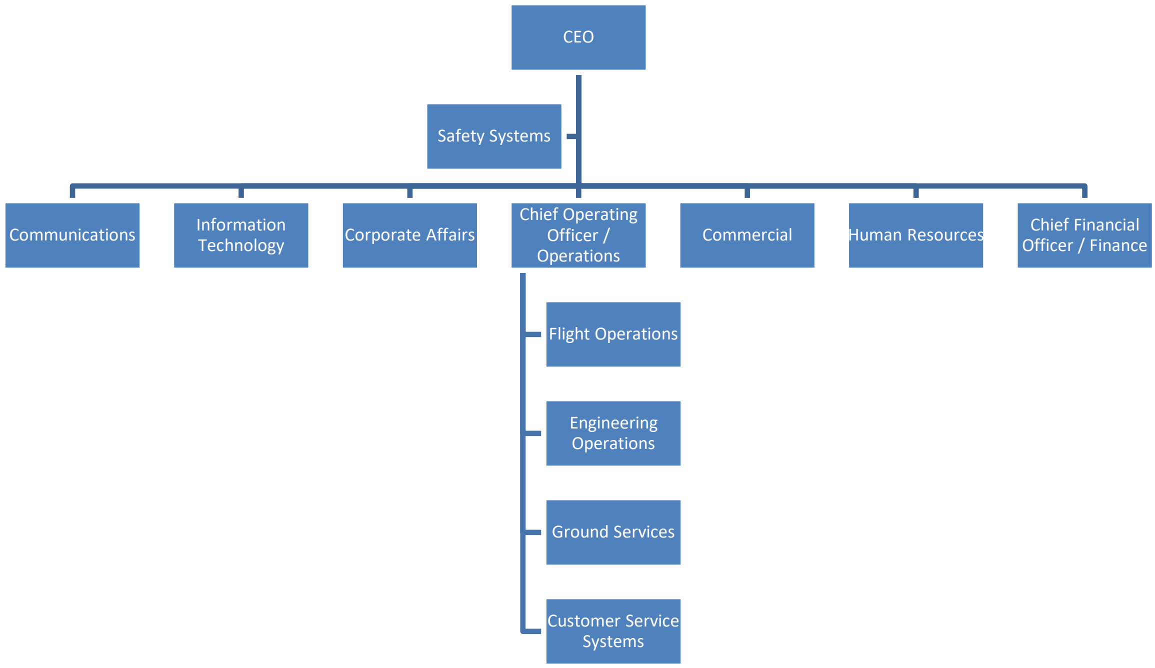

Figure 62: EmeraldJet's organisational structure

At the heart of the airline's operations was the Operations Control Centre (OCC). The Centre co-located many of the support teams that ensure scheduled flight services were delivered, and to deal with a range of contingencies, such as bad weather, aircraft breakdowns, heavy air-traffic, and other factors that would affect schedule integrity.

Figure 63: EmeraldJet Operations Control Centre makeup

Operating from the airline's main hub airport, the multi-disciplinary team was made up of the following units:

- **Navigation Services:** Primarily responsible for generating flight plans on behalf of the Flight Crew, considering issues such as weather, aircraft defect operational limitations, loads, and fuel requirements. Navigation Services also maintained the database system used to model and generate such plans (including navigation, aircraft performance, and schedule information data).
- **Aircraft Movement Control:** Managed the airline's flying program with the aim of maintaining schedule integrity while also maintaining safety and regulatory compliance. Recovery of the schedule from disruption was also a major function of Aircraft Movement Control.
- **Meteorological Surveillance:** played an important role in the managing of on-time performance for EmeraldJet. Their early warning on meteorological conditions such as storms, icing, and head and cross winds allowed an early start on contingencies to combat irregular operations.
- **IT Support:** The OCC was highly reliant on a variety of complex software systems, connected across the globe via information networks. These systems included aircraft movement control systems, dispatch control systems, airport traffic information systems (especially for managing slots in and out of congested airports), passenger and cargo booking systems, aircraft configuration tracking systems, and crew control software.
- **Cabin Crew Operational Support:** provided immediate and suitable support to cabin crews ensuring they were fully supported in their role on a 'day of operations' level. This team dealt with a broad range of situations to find the best solution for any issues crew faced when on duty.
- **Revenue Operations:** provided input on which flights represent greater importance to EmeraldJet to ensure an on-time performance, or which flights would have a lesser impact if cancelled. If flying network disruptions required the cancellation of a flight, Revenue Operations would advise which flight was less likely to impact both customers, as well as the airline from a compensation and reputational damage perspective. Also, it coordinated responses for airport staff and the communications function of the airline to communicate with customers during disruptions.
- **Crew Control:** Responsible for maintaining schedule integrity by controlling crew movements and minimising or eliminating delays. This involved managing a complex matrix of crew connections between inbound and outbound flights (a matched crew might stay with the same aircraft throughout the day, but they may also change over another tail number in the middle of the shift – this could cause delays if inbound aircraft were late). Crew control also ensured that crews did not exceed duty time limits, an important safety, and regulatory requirement.
- **Flight Crew:** Like the cabin crew operational support team, the Flight Crew team provided real-time support to flight crews on the EmeraldJet network, covering a wide range of technical and crewing matters.
- **Maintenance Operations:** Was the central point of contact for all engineering operational issues associated with the fleet. This role is expanded upon shortly.

This multi-disciplinary environment, led by the OCC Duty Manager, allowed the airline to examine the impact a delay has on the rest of the fleet and the rest of the day's schedule, and to identify workarounds and solutions to bring the schedule back-on-track. This included determining, if required, what services could be cancelled that have the least network disruption to allow the rest of the network to recover. While the airline published a timetable, sticking to it was a complex challenge.

20.1.3 Complexity: The nature of the beast

The airline industry is notorious for complex and often unpredictable challenges that can 'break' a company if not adequately managed. From macro events, such as SARS and fuel-price spikes, to market forces, to localised situations such as weather, the airline industry is subject to a variety of disruptive (both in an immediate, as well as follow-on type of way).

Seeking to understand the role of engineering in this case study requires a reflection on the complex challenges this sector presents. This 'complexity survey' is by no means complete, and merely reflects some of the challenges faced by airlines, and in particular, those that have a flow-on effect for the Fleet Management Group in some form.

20.1.3.1 Operational complexity

In the most simplistic of theory, an airline is merely a network with pre-planned services that follow a schedule; in other words, a planned sequence. However, the 'real world' presents challenges and uncertain factors that seek to throw that schedule out. In addition, these are factors that can also escalate costs, despite a lack of customer price elasticity for the 'product' (i.e., flights) on offer. To illustrate, Figure 64 shows the significant complexity for just one day's operation with a fleet of less than two-dozen aircraft.

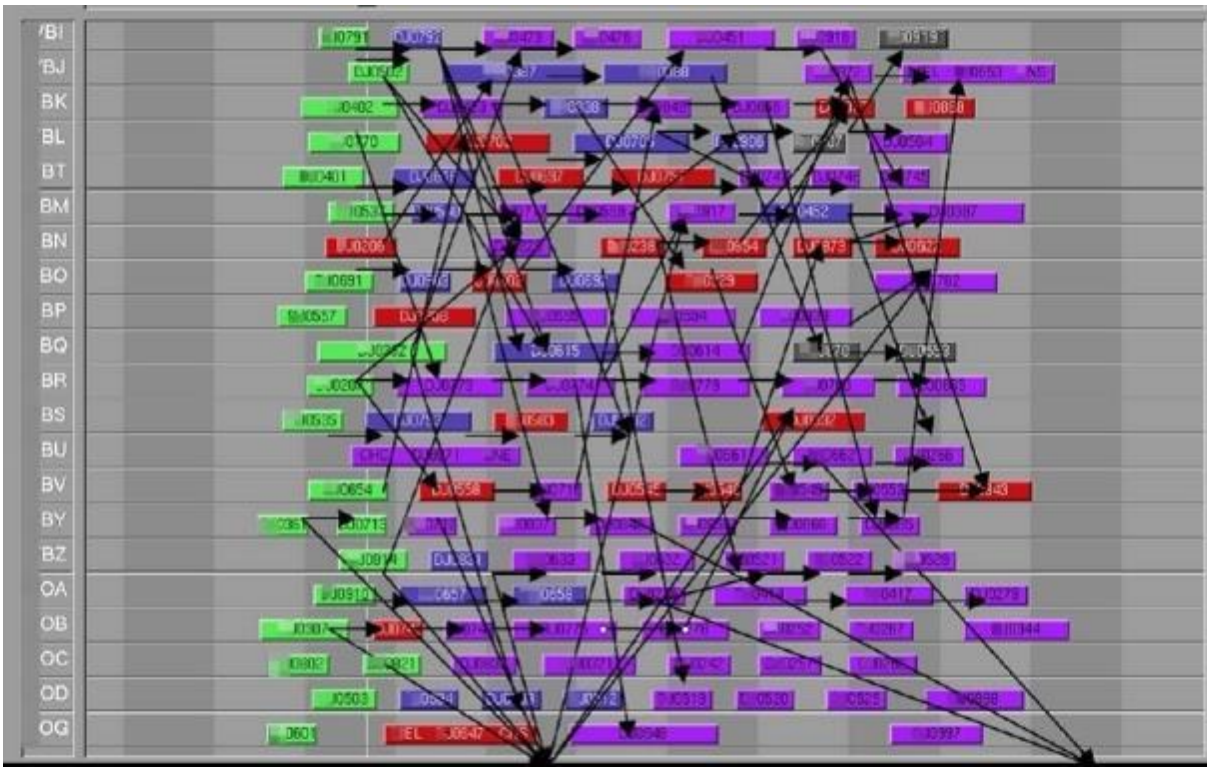

Figure 64: Snapshot of part of the fleet for one day's flying at EmeraldJet. Note arrows are crew connections (i.e., flight crew move from one service on one aircraft to another, rather than staying with the same aircraft the whole day).

Many factors can potentially cause an operational disruption, be a constraint that the airline must consider when planning the published schedule, or be a constraint when devising recovery options for any potential disruption. They include:

- **Crewing Issues:** for example, duty hours, connections, or lack of hotels
- **Aircraft type:** availability, cross-referenced to sector requirements, poses logistical challenges (e.g., is this the equipment typically used on this sector with the correct number of seats, or can the aircraft land at a certain airfield with a particular increased weight modification to the airframe?)
- The **published schedule** may be ambitious
- **Airport curfews:** these can place considerable constraints and inhibit more straightforward schedule recovery options
- **Passenger loads** and the prospect of rebooking passengers from other disrupted flights
- **Overnight ports:** some ports are only equipped with a 'turnaround' capability, and don't possess a maintenance presence required to conduct minor overnight checks, nor are crew based at that port; as such, aircraft cannot be parked overnight in that port
- **Aircraft defects with operational limitations:** While aircraft can be dispatched with some specific non-operating equipment (see MEL below), this does impose some restrictions on where the aircraft can fly
- **Scheduled Maintenance:** affects availability of aircraft for service
- **Pre-organised staffing/tooling/parts:** If an aircraft with an issue lands at a port without an engineering presence, it can take longer to fix than at other ports as maintenance crews and parts often need to be flown in.

All these issues (and more) affect multiple aircraft and personnel on the day, with a flow-on effect possible for many days on. Further still, each of these issues may compound a disruption or issue. For instance, inclement weather causing a delay in one port can cause an aircraft to be perpetually late throughout the rest of the day. If this aircraft must be routed through a port with a curfew, onto its final destination for a maintenance check, there is a chance the aircraft might be grounded at that curfewed airport. This means the maintenance check isn't performed, which means the next day, the airline is an aircraft short until that check can be performed. This is one such example of many issues that must be managed to ensure the ongoing, timely delivery of flights (travel services).

20.1.3.2 Business complexity

The airline sector faces complexity that arises from the nature of the marketplace. These include:

- **Regulatory complexity:** Airlines across the world are subject to many forms of regulation that govern most facets of their business. Safety regulations are palpable, but government rules concerning ownership, employment arrangements, taxation, and security can also seriously affect how the business is run.
- **Variability of circumstances:** Whether it is volatile or high fuel prices, or major global events that can disrupt traffic patterns and demand, airlines are subject to conditions that are both variable and often unpredictable.
- **Customer expectations:** travellers' expectations regarding on-time performance, in-flight product, destinations, prices, and loyalty programs all make for a dynamic environment.

20.1.3.3 From an engineering perspective

The technical context of an airline is also complex, namely due to the sophistication of modern commercial aircraft. With large volumes of information exchange between the airline and the aircraft manufacturer, sub-system OEMs and other service providers, keeping on top of managing the fleet is a challenge.

Perhaps one respite, in comparison the previous case study, is that the business complexity affecting aircraft fleet management is a little more pronounced (e.g., new fleet purchases, destinations, and in-flight product) rather than iterative. The challenge is perhaps more on a persistent expectation to deliver aircraft availability, and where possible, improve. One other challenge is managing a fleet of leased aircraft that must be maintained by lessor requirements, and where the aircraft must be returned in a set condition to the lessor.

20.2 The Fleet Management Group

20.2.1 Role and leadership

An important distinction needs to be drawn on the role of the Fleet Management Group: it was the dictator, formulator, and often implementer of physical, hands-on maintenance activity. Under NAA regulations, EmeraldJet was responsible for the airworthiness of the fleet, even if part of the physical maintenance activity was outsourced (which it was). Thus, the Fleet Management Group's structure was devised to reflect the activities and responsibilities imposed upon it by the NAA's regulations.

The FMG was headed up by the Group Manager who was responsible to the Chief Operating Officer of EmeraldJet for the effective commercial operation of the Group. This included setting and implementing Group strategy, Group financial management, and managing performance of the Group and outsourced service vendors. The GM did not, however, have a technical approval, and relied on the Chief Airworthiness and Maintenance Controller (CAMC), via the Maintenance Standards unit, to manage the technical discipline aspects of the Group.

The Group was structured along eight key lines, as indicated in Figure 65.

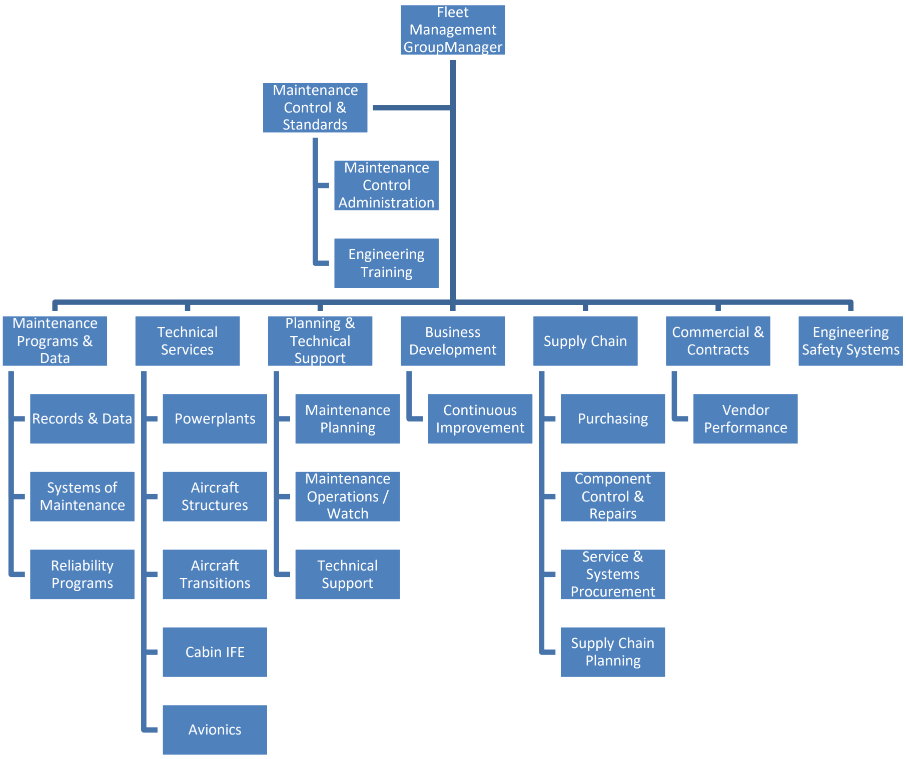

Figure 65: Fleet Management Group organisational structure

20.2.2 Maintenance Vendors

EmeraldJet had a limited line maintenance capability (initially called *EmeraldTechnik*), so FMG also contracted in another line maintenance provider at smaller ports. Heavy maintenance checks were performed by other heavy maintenance service vendors across the world. All maintenance was overseen and subject to control by the Maintenance Standards unit, and Maintenance Operations unit.

20.2.3 Maintenance Programs & Data Unit

The Maintenance Programs & Data unit was responsible for most of the technical data and information that defines the maintenance activity EmeraldJet engages in.

This responsibility was broken into three streams:

- Records & Data Control
- Systems of Maintenance Management
- Reliability Programs

20.2.3.1 Records & Data Control

A fundamental of aircraft airworthiness is control over records, information, and data. The Records & Data Control team ensured:

- Proper records were kept of all maintenance actions and engineering decisions
- The collection, collation, and entry of flight data entries, such as pilot technical logs, defect reports, usage data, and other parameters recorded on aircraft systems
- That all changes to aircraft were fully documented and accounted for, such as part changes, the embodiment of approved modifications, and the execution of repairs
- The availability of approved documentation and publications used in maintenance and engineering work. This included Maintenance Manuals, company maintenance procedures, and technical standards.

20.2.3.2 System of Maintenance Management

Each tailnumber in the fleet had its own System of Maintenance, a maintenance program that consisted of a list of maintenance tasks to be performed, with an action trigger for each item (generally flight hours, but also number of cycles or calendar time). As each aircraft could vary slightly at the detailed level from others in the fleet, these SoMs had to be approved and maintained throughout the aircraft's life. The SoM team ensured that each aircraft's maintenance program was up-to-date, considering both updates from aircraft manufacturers, from the National Airworthiness Authority, and from Reliability Programs who made recommendations to alter the SoMs based on data-driven experience.

20.2.3.3 Reliability Programs

The airline's approved Reliability Program tracked the actual in-service experience of aircraft systems and subsystems. This tracking was benchmarked against 'performance targets,' and was used to review the System of Maintenance or provide insights to manufacturers or regulatory authorities to make changes to component designs.

In addition to the formal monitoring of reliability parameters, the Reliability Programs Lead was also in charge of coordinating reportable defects to the NAA. Whilst investigation of these defects lied (generally) with Technical Services, the Reliability Programs Lead coordinated and monitored the investigation and rectification of any outstanding anomalies.

20.2.4 Planning and Technical Support Unit

This unit not only provided services to the rest of the airline, but it also was the engineering voice to operations by been the representative of the Fleet Management Group to operational units across the airline.

20.2.4.1 Maintenance Watch

The Maintenance Watch team played a critical role in the airline's day-to-day operations by working to reduce aircraft-related disruptions. They were the representatives of the Fleet Management Group into the OCC and provided 'live' technical support to engineers and technical staff across the EmeraldJet network.

Much of Maintenance Watch's (MW) work was focused on reactivating aircraft when minor defects or anomalies manifested in aircraft. Defects ranged from inoperable subsystems (for which redundancies were built into the aircraft design), right through to missing panels on the aircraft. When a defect was identified, whether it be when preparing the aircraft for next flight or in-flight itself, MW was the liaison point within the Operations Division to determine an immediate course of action. In many instances, this involved determining whether the aircraft could continue flying with that defect, and this was done by consulting the Dispatch Deviation Guide or the Aircraft Maintenance Manual (AMM)[27].

In more major cases, aircraft could be declared as 'AOG' or Aircraft On Ground, a situation where the aircraft was 'grounded' pending a repair or maintenance action. Naturally, AOG was a significant disruptive situation for the airline's schedule and had to be resolved quickly. In such instances, the MW team worked with the Technical Support (or Technical Services) function, maintenance providers, parts and logistics providers, and any other parties, to rectify the problem as quickly as possible to return the aircraft to service.

This included significant coordination efforts to find parts, approved fixes, and qualified staff to implement a fix. This last point was of particular focus for the airline, as not all ports that the airline flies to has access to qualified maintenance personnel. In such instances, a maintenance engineer had to be flown into the port to repair the aircraft. Most major ports had their own full-time line maintenance staff, but where 'black holes' appeared, MW had to coordinate both the maintenance resources, as well as keep the rest of the OCC informed as to progress.

Aircraft that sustained damage in-service would often take longer to be attended to; however, Maintenance Watch was engaged in assessing how fast repairs could rectify the damage, and return aircraft back 'online' again.

In addition to the emphasis on defect management and aircraft prompt re-activations, the Maintenance Watch function also had responsibility for the following:

- **Technical 'helpdesk':** Maintenance Watch also provided a 'first level' technical support to Line Maintenance and other operational units who had maintenance-related queries. MW had at their disposal a wide range of aircraft manuals and information which could help answer or clarify any ambiguities that arose in flight or at the gate during a turn-around. MW also acted as a 'helpdesk' to Line Maintenance maintainers in the rectification of defects.
- **OCC Support:** In aid of enabling on time performance (or schedule recovery), Maintenance Watch was responsible for providing updates to other operational units across the airline (via the OCC) on progress and expected return-to-service status of affected aircraft. It also advised on any restrictions imposed on aircraft operating on the day (for instance, a permissible defect that restricted an aircraft from operating into certain airports). They were also engaged in finding 'workarounds' to bring other aircraft out of maintenance faster to meet a gap (for example, by deferring a maintenance task that had been brought forward).

[27] The DDG was made up of two approved publications, including the Minimum Equipment List, and the Configuration Deviation Guide, which provided authoritative direction on permissible unserviceabilities, and any caveats on such permissions (such as rectification limits, operational restrictions, such as not operating over water, and warnings to be presented to the flight crew).

- **Daily Status Report:** To aid effective flight operations, Maintenance Watch published a real-time overview of the technical status of each aircraft, called the Daily Status Report. This helped flight crews understand the state of the aircraft they would be flying, and to be aware of any limitations imposed on that aircraft due to carried-forward defects or recent troubleshooting in response to previous crew reports. This information was also used by movement controllers to ensure that routes with specific requirements (e.g., reverse thrust availability to land on shorter and narrower runways) are not allocated aircraft with this functionality inhibited.

20.2.4.2 Maintenance Planning

At the centre of the very delicate balancing act between ensuring aircraft availability and ensuring aircraft airworthiness was the Maintenance Planning function. This team achieved this by creating a series of rolling plans for aircraft that had to be taken 'offline' for scheduled maintenance, ensuring it met maintenance task requirements, but also worked with the OCC members to produce a list of aircraft allocations for flying operations.

Most of their work centred on line maintenance and light base-maintenance tasks – that is, tasks that could be completed at the gate, or in a maintenance hangar with limited capabilities. Such maintenance tasks were generally performed overnight, although some took a few days. The team also planned for when heavy base maintenance was to be performed, and when the aircraft was to be taken offline. However, it was line maintenance planning that was more dynamic and critical to aircraft availability, as sometimes there was 'slack' in the planned maintenance activity to have an aircraft cover another aircraft that had gone AOG. Heavy checks, on the other hand, saw aircraft removed from service for weeks or months at a time and couldn't be 'mixed around' to meet a shortfall in capacity.

Figure 66: Scheduled line maintenance actions, and impact on network operations.

It was a complex, dynamic and fluid endeavour, as seen by the complexity of Figure 66. In what might be described as a game of 3D chess, the team worked on four time horizons:

- **Day of operations:** Liaise with outsourced maintenance providers who were performing maintenance tasks to monitor progress. Any delays in tasks might've mean working with Aircraft Movement Controllers to swap out that aircraft for another to minimise disruption for the day's flying program.

- **Short term plan:** This was the action plan for the next seven days, rather than a projection. It identified specific work packages that had to be completed, including defects that had to be addressed before any time limitations imposed by the approved publications took effect, as well as any items that had to be accomplished in that seven-day cycle. The team also addressed where these maintenance actions need to be performed (i.e., which port the aircraft neeed to be positioned to for servicing which generally became the last flight of the day), what maintenance team would be allocated, and what spares needed to be sourced from stores and sent across. Also, network planning allocated aircraft tail numbers to the planning flying programs for that coming seven days; hence the maintenance plan had to be thoroughly detailed.
- **Medium-term plan:** Consisted of a 30-day forecast of the likely work that needed to be undertaken on each aircraft in that time-period, including known defect rectification, scheduled visits, and semi-urgent additional inspections as mandated by the manufacturer and regulator. It was correlated with a separate 30-day flying program plan devised by network planning, with a list of required aircraft types (quantity and starting port), although specific tail numbers were not assigned. This flying plan generally drove the way in which the Fleet Management Group could provision the right number of aircraft for the plan, although the Group also needed to work with network planning to find a way around any shortfalls (such as cancelling or rescheduling a series of flights some days or weeks in advance).
- **Long term plan:** This was the list of aircraft and their predicted 'pull date' from operation for a heavy base maintenance visit for some weeks or months. Such visits were out of EmeraldJet's capability (not having facilities or technician resources), and thus contracts were placed with specialised MRO providers to undertake heavy maintenance visits.

20.2.4.3 Technical Support

Whereas Maintenance Watch provided a 'level 1' real-time support for most routine matters, Technical Support (TS) lent a 'level 2' assistance for problems that needed more research, or potentially required careful consideration and analysis. Like Maintenance Watch, Technical Support was a 24/7 operation within the airline.

It lent assistance in four main ways:

- **On-call support:** TS provided more in-depth support for more challenging or borderline issues in the operational environment. Some problems required troubleshooting to diagnose the issue properly. With access to a fuller publication set, as well as reach back to Technical Services, and other advice providers, TS was able to provide remote support to maintenance crews at the gate.
- **Logistics supply coordination:** Technical Support was the parts distribution initiator, sending orders through to the Supply Chain function for order delivery and fulfilment, and ensuring parts were provisioned promptly.
- **Technical oversight:** EmeraldJet, by law, was required to have oversight and control of maintenance performed on their aircraft, even if the maintenance provider was a different company. Whilst line maintenance providers were oversighted by the Maintenance Standards unit, oversight of heavy maintenance providers was performed by Technical Support. This oversight consisted of EmeraldJet technical representatives present and onsite to monitor the

accomplishment of maintenance, ensure approved procedures were followed, and to verify that the final product was to standard.

- **Engineering support representation:** In addition to supporting line maintenance providers, Technical Support also acted as the entry point back into the EmeraldJet Fleet Management Group for the outsourced heavy maintenance providers. During such visits, further inputs and technical instructions were often required of EmeraldJet for the maintenance provider to carry out, such as repair schemes for damage found during the check. Technical Support coordinated a response to these queries and ensured that only approved data and instructions were transmitted to the maintenance provider for implementation.

Whilst Technical Support had access to the full suite of approved aircraft publications which were used in helping resolving technical matters, there were many instances that required something deeper. In such situations, Technical Services operated as a coordinator, rather than as a creator or assessor, of deeper technical solutions. It did this by reaching into other legally approved and authoritative sources:

- **Approved External Engineering Firm:** TS were responsible for maintaining the Engineering Support Request (ESR) system whereby an external, approved engineering firm provided legal, approved data and instructions for matters that were outside the scope of existing manuals. These included repair schemes and authority to fit parts that were not yet in the airline's record system (and need to be legally inducted into a controlled pool).
- **Technical Services:** The internal Technical Services unit (as opposed to Support) could provide a level of insight and expertise on issues. However, they didn't possess an authority to generate new approved data and instructions to cover specific, unique situations (hence the ESR process).
- **OEMs:** Technical Support coordinated queries and requests submitted to aircraft and subsystem OEMs. These official responses were considered to be approved data and authoritative advice or instructions.

20.2.5 Technical Services Unit

Much of the Fleet Management Group was concerned with more immediate factors, such as availability for flying operations, fleet activation and ensuring maintenance tasks were completed with minimal disruption. The Technical Services function, however, took a more longer-term and foundational role within the Group. It asked important questions in the effort of ensuring the long-term airworthiness and viability of the EmeraldJet fleet.

In this multi-role unit, Technical Services was the airline's major Embedded Engineering Function. Among other responsibilities, its core business was managing continuing airworthiness; managing the accomplishment of maintenance tasks was not in its purview. While other units across the FMG might've been the formulators and implementers of tasks that contributed to continuing airworthiness, Technical Services 'owned' the control of the configuration of the fleet. In a sense, they controlled the physical and functional aspects of the aircraft that were in EmeraldJet's fleet, as well as the technical policies that dictated how the aircraft was to be maintained, serviced, repaired, and operated (with input on systems procedures used by flight crew).

However, Technical Services did not just possess an airworthiness responsibility, also providing a unique 'service offering' to the Fleet Management Group. It held responsibility for reliability management and improvements, cost-of-ownership management, initiatives that led to higher availability, as well as the implementation of in-flight product improvements (such as in-flight wireless internet). Its key responsibilities included:

- Continued airworthiness policy and management framework for the EmeraldJet fleet
- Fleet reliability management and enhancement (with insights generated by Reliability Engineering)
- Fleet cost of ownership/possession management
- Product and capability enhancement implementation.

Whilst most of the FMG was staffed with LAMEs, the Technical Services unit was mostly staffed by professional engineers (and was required to be led by a professional engineer). It was the professional engineering outfit within the Fleet Management Group, providing specialist technical oversight and assistance.

20.2.5.1 Domains and work program

Given the multivariate nature of the unit, the team structure was split into five key domains:

- Structures
- Powerplants
- Avionics
- Cabin & Inflight Entertainment Systems
- Aircraft Transitions.

In addition, the unit operated and discharged its responsibilities through a work program of six key areas:

- Continuing Airworthiness Evaluation & Control
- Aircraft Technical Management Policy Management
- Oversight of outsourced Approved Design Engineering firm
- Modifications and Technical Projects
- Engineering Support.

20.2.5.2 Continuing airworthiness evaluation & control

Technical Services had a strong technical policy component to its role. Whilst much of the FMG was operationally focused, Tech Services played somewhat of a sentinel and custodian role in managing the continuing airworthiness of the EmeraldJet fleet.

This was done on two fronts:

- Controlling the configuration of the fleet
- Monitoring and evaluating information that suggested changes needed to be made to fleet configurations.

Controlling the configuration of the fleet was predicated on the Certificate of Airworthiness, a document that asserted for a particular tail number that it was a faithful replica of the original, approved design. Technical Services' role was to ensure the preservation of the configuration of the aircraft as it was when the CoA was granted before joining the fleet. This was done by control of the Aircraft Technical Management Policy* (described shortly), and via annual processes to verify and audit maintenance records to ensure the aircraft configuration was correct. This configuration not only included the physical arrangement of equipment onboard, but ensuring there was a central record of what was installed, and that the Aircraft Technical Management Policy was valid for that configuration (for example, the maintenance manual covers a 'model 3' electronics box, not a 'model 2').

Maintaining CoA validity is not a one-off event given the dynamic and complex nature of technical issues that face sophisticated aircraft types. As in-service experience grows, there may need to be changes made to this configuration – in other words, altering the aircraft away from the original design (in a highly regulated and controlled manner) as circumstance dictates. This process was initiated by the evaluation of continuing airworthiness information to assess whether such changes needed to be developed or adopted and then embodied in the airline's fleet.

The Technical Services Unit evaluated continuing airworthiness information from several streams including:

- Airworthiness Directives
- Service Bulletins, Service Letters or other advice from aircraft OEMs
- Defect investigations (which Technical Services also participated in)
- Insights from the reliability program.

As part of the evaluation process, Technical Services had to decide whether any actions or mandated requirements needed to be issued to other units of the FMG for embodiment into the fleet, or potentially broader through the airline (such as Flight Operations or Flight Crew training). The review of this information also often lead to a change in the airline's Aircraft Technical Management Policy[28].

Technical Services was engaged in a complex and dynamic task of ensuring that EmeraldJet's aircraft continually meet the safety condition intent outlined in regulations. They acted as the custodians of what the aircraft had to conform to, a never-ending pursuit due to the sophisticated nature of the aircraft they operated.

20.2.5.3 Aircraft Technical Management Policy regimen

The output of this Continuing Airworthiness Evaluation and Control activity was Technical Service's next important area of work – maintaining and promulgating the complete Aircraft Technical Management Policy.

In this instance, Technical Services' role was to provide a consistent and accurate single point of truth for any action to be imposed on an aircraft in the fleet. Whilst the Technical Services function did not have direct control over the planning of maintenance, nor over the processes used in managing maintenance activity, it did control the aircraft-specific information and instructions that were required

[28] The term "Aircraft Technical Management Policy" is an invention by this study, and covers the current and valid range of information, instructions, standards and requirements that dictate the use, operation, maintenance and overall definition of the aircraft. This policy is a set of authoritative and exclusive publications, documents and datasets that have been qualified as ensuring, or leading to a restoring, of a safe condition for the aircraft. These are often referred to as "Instructions for Continuing Airworthiness." This study invents the term ATMP to find another way of expressing what ICA, along with other maintenance and engineering data provided to airlines, ultimately covers.

to be adhered to or followed whenever any work was performed on an aircraft. Its role was to ensure the continued validity, and in some instances continued approval, of this Policy.

This Policy was promulgated either as official publications, documents or datasets (effectively binding reference information), or as specific action directives to ensure a pressing need was accomplished promptly. These included:

- Promulgation of endorsed Service Bulletins & Service Letters and ensure they were placed into Maintenance Planning requirements
- Instructions to implement Airworthiness Directives, and ensure they were placed into Maintenance Planning requirements
- Maintenance Planning Data
- Aircraft Maintenance Manual suite (including other service publications such as Trouble Shooting Guides, Wiring Diagrams, etc.)
- Dispatch Deviation Guide, consisting of the Minimum Equipment List and Configuration Deviation Lists
- Aircraft Flight Manuals
- Aircraft Performance Data
- Directives for approved changes to System of Maintenance (compiled and administrated by the SoM unit).

Most of this Aircraft Technical Management Policy was originally devised by the aircraft manufacturer. However, because of local regulatory requirements, there were areas where more stringent requirements had to be followed, and thus Technical Services monitored changes in information and instructions from the manufacturer to ensure it complied with local requirements.

20.2.5.4 Oversight of outsourced Approved Design Engineering firm

As part of Technical Services' remit of controlling the configuration of the aircraft (and thus controlling any deviations away from the original design), the unit was responsible for managing the relationship and quality of the contracted Approved Engineering Design firm.

This firm held an authorisation from the local NAA to make authorised interventions to address situations outside the scope of the Aircraft Technical Management Policy. These included devising repair schemes, designing new cabin layouts (from a technical compliance perspective), or authorising other actions on the aircraft that were beyond the normal scope of the Policy. This firm was required to follow strict internal processes to analyse engineering solutions for compliance against design regulations, generate instructions, and provide any further Instructions for Continuing Airworthiness (ICA) following that intervention.

Whilst other units within the FMG could engage and lodge a service request with this external engineering firm, the oversight of the firm's processes and activities rested with Technical Services.

20.2.5.5 Modifications and technical projects

Beyond the strict airworthiness regimen, Technical Services was also involved in project management and delivery, particularly of major modification and upgrade programs. One activity the unit was almost constantly involved in managing was in-flight product upgrades – that is, cabin refreshes, in-flight entertainment systems, and customer wireless internet access. Technical Services managed these capital upgrade programs, including design definition, seeking regulatory approval, scheduling of aircraft (in conjunction with Maintenance Planning during a heavy maintenance visit), and actual implementation of retrofits.

Aircraft induction or disposals (or return to lessors) was another a key area of focus, sufficient enough for it to be one of the five domain areas. It involved the complex task of inducting new aircraft into the fleet, including obtaining the initial Certificate of Airworthiness, ensuring conformity of the aircraft (including the cabin) to the specification set out at order, and ensuring the aircraft's presence in the airline's tracking systems were established (e.g., historical records were accounted for and formed part of the airline's records). Disposing of an aircraft out of the fleet, whether to be sold or returned to lessor, followed a similar round of activity – ensuring records were up-to-date, and that the aircraft was delivered in a configuration acceptable to the new operator.

From time-to-time, the unit was also engaged in other smaller projects, such as product/equipment evaluations/trials, and aircraft purchasing analysis and decision-support.

20.2.5.6 Engineering support & solutions

Technical Services' presence in the FMG also presented a 'level 3' technical support capability to the airline. For any abnormal technical matters, they were a veritable 'brains trust' – highly experienced and trained professional engineers who could provide advice on problems and anomalies encountered, and find a way to resolve them. Whereas other units were very operationally focused, Technical Services found themselves examining issues with the fleet, identifying solutions (often provided by the OEM), and assessing those solutions, before recommending their implementation. They were the thinkers – the deeper domain specialists the airline could call on to examine less routine, but more complex or systematic problems for the fleet.

20.2.5.7 A unique role

Maintenance Operations was engaged in ensuring maintenance tasks were completed in a way that also facilitated maximum fleet availability (or responding to AOG situations), and Programs and Data played a data management and insights generation role within the Group. However, Technical Services was responsible for the more conceptual (but still very real) continued airworthiness of the fleet, as well as ensuring the fleet represented maximum utility and viability for the airline in the longer term.

20.3 Maintenance Standards Unit

The Maintenance Standards unit was headed up by the Chief Airworthiness and Maintenance Controller (CAMC) who had responsibility and authority to control all maintenance on EmeraldJet's aircraft, whether by EmeraldJet or by its approved service vendors. The CAMC was an approved appointment by the NAA and had signoff authority on all technical matters and procedures within the Group. While the Group Manager was be in charge of the overall outfit, all technical aspects of the Group were under the CAMCs supervision and authority.

To support this duty, the Maintenance Standards unit also encompassed the Group's training function, as well as an administrative function to practically oversee maintenance that had been performed. In collaboration with the Business Development unit, it also developed and approved procedures and standards that the Group was required to adhere to.

20.3.1 Other units within the Group

There are other more logistical, administrative or support units that made up the Group but are not reviewed in detail for brevity. They include:

- **Business Development:** The unit responsible for supporting and improving business processes, as well as the suite of IT systems and infrastructure used by the Group
- **Supply Chain:** This unit was responsible for components and spare parts. This included forecasting, purchasing, warehousing, distribution, and warranty management. It also was responsible for managing repair agreements with vendors for parts and ensuring that parts sent for maintenance/overhaul were done so in accordance with regulations and that the repair process turnaround times were managed.
- **Commercial and Contracts:** The unit responsible for oversighting and managing outsourced maintenance service providers from a contractual and commercial performance perspective.
- **Safety Management:** Reporting into the whole-of-airline safety management function, this unit monitored maintenance errors, other safety performance metrics, and performed other investigations to ensure the safety capability of EmeraldJet and the Fleet Management Group.

20.3.2 Other 'engineering' functions across EmeraldJet

It's important to touch on other aircraft 'engineering' activities within EmeraldJet that were not captured in the exposition of the FMG or Technical Services. These included:

- **Performance engineering:** This involved using aircraft performance data to plan new routes (particularly precise take-off and landing policy and procedures), monitoring fuel burn profiles, setting and monitoring optimal cost-index parameters[29], and to ensure that the airline was operating with sufficient, safe operating margins. These functions were instead performed by the Flight Operations Group. Whilst much of the daily performance engineering activity was automatically generated, flight performance databases did need to be maintained, and the overall policy needed to be oversighted by a performance-engineering specialist.
- **Weight & balance:** Closely connected to performance engineering was the importance of controlling the weight and balance of aircraft in the fleet. At the operational level, this involved producing loadsheets for cargo loaders and flight crews to accurately pinpoint the centre-of-gravity for take-off (a safety critical action). Again, such operational calculations were mostly automatically generated within the OCC. Also, aircraft required periodic re-weighing to verify that such weight-and-balance assumptions used in calculations were valid. However, there was also a policy-setting and oversight function which again required an engineering specialist. Again, this was held within the Flight Operations Group, although the aircraft weighing program was oversighted by Maintenance Standards.

[29] Indices that tell flight management computers whether to prioritise speed or fuel economy in cruise

It's this example of 'distributed engineering' for which this study uses the term Embedded Engineering Function; it may not be the one organisational unit, but it was informed by a common disciplinary core (i.e., engineering) and was overseen by a professional engineer in some capacity. As can be understood, however, these two facets of the EEF, in this context, are positioned in the Flight Operations Group given the closeness they have to enabling operations, rather than purely controlling airworthiness.

20.4 Observations

Whilst preparing this case, there were some factors or unspoken structures that emerged that has helped formulate and understand the Fleet Management Group. They're not facts taken from the case; rather interpretations that help create a clearer understanding of the situation being explored.

20.4.1 The nature of the Fleet Management Group

The way the Group conducted its business was not merely reflected in its structure or even allocation of functional responsibilities, but a fuller picture is found by also considering *ongoing routines*. It thus goes without saying that the Fleet Management Group's business was highly operational, with these routines set on constant repeat. Unlike some forms of engineering, such as extensive product development, there was little downtime to self-reflect (without effort, at least), and efforts are constantly focused on averting disruption or disaster.

20.4.2 Levels of engineering capability

It became apparent during case research that the Fleet Management Group exhibited its noetic technical capabilities on three levels (see Figure 67). These levels represent progressively deeper levels of engineering nous and problem-solving abilities that were on-call for the airline to use. Whilst this may not be overly revelatory, it does help narrow in on just what exactly is professional engineering, and what is more a trades-application of engineering knowledge.

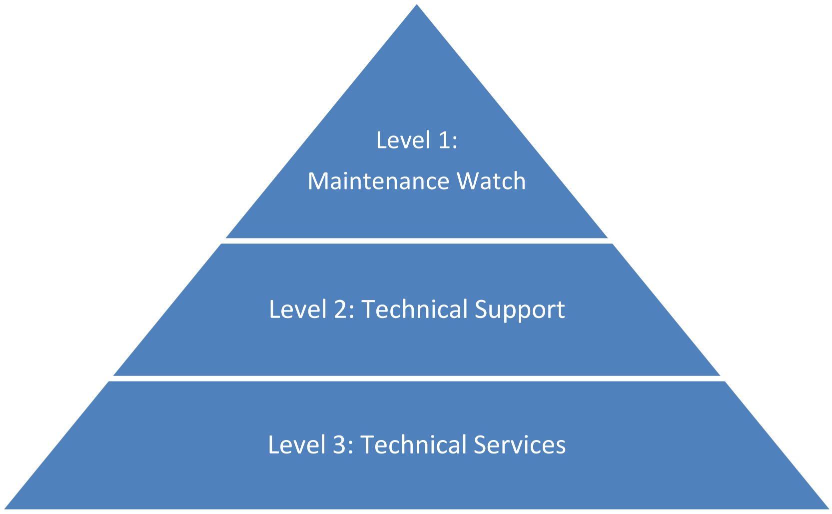

Figure 67: Levels of technical capability

20.5 An unfinished story

This chapter has portrayed and described the outfit responsible for ensuring EmeraldJet's fleet is activated, available for flight operations, and was above all, airworthy. It has covered the complexities of the business of air transport and examined the inner operational workings that make an airline work. It's especially highlighted the key areas of the Fleet Management Group that help it discharge its responsibilities.

However, as instructive and applied this depiction has been, not everything was as it seemed. There is more to this story – a particular episode of time where the Fleet Management Group had to rethink its role, re-examine how it engaged with the broader airline, and reshape the way it conducted its business. This is portrayed in Chapter 21.

CHAPTER 21

Rethinking EmeraldJet Airlines' Fleet Management Group

Case Study 2

21.0 Reshaping the Fleet Management Group

Chapter 20 introduced EmeraldJet Airlines, describing its operation, plus detailing the Fleet Management Group. It covered how the Group functioned and described the routines which helped it work towards the airline's objectives.

This all sounds business-as-usual. However, this study investigated the airline at a fascinating stage of its story where EmeraldJet embarked on a new direction, sparking a large chorus of change efforts across the organisation. It included a scene where senior executives were asking deep questions about the nature of the business they were in, the way the airline should adapt to that dynamic business and the way it should seek to position itself. Out of this introspective season, questions were asked about how things could be done different, or better.

This included the Fleet Management Group, whose contribution to the company was felt to be quite pedestrian. In the words of the Group's Manager, it was a 'traditional engineering' organisation, not infected with the same passion and culture of the rest of the airline.

21.0.1 Reforming Group essence

Organisations are not entirely composed of organisational structures and processes, but are distinct due to their inner-workings – the 'glue' and the energy at their core that guides and drives their efforts. It's the sentiment behind Weick's idea of "the organizing" espoused in Chapter 5.

The Fleet Management Group's quality, regulatory compliance and technical nous were not under any review. What existed was a considered and experienced executive opinion by the airline's leadership that the Fleet Management Group was not living up to corporate expectations and could be developed into a more sophisticated and business-aligned outfit.

This Chapter explores this epoch in the Group's existence where it had to re-find its true essence and realign itself to the goals of the broader airline operation.

21.1 Got that management feeling

About ten years after EmeraldJet's launch, it went through a phase of introspection, seeking to understand where its market was going, how the airline could adjust its business model to earn more revenue (and profit), and how it would best position itself to meet shareholder expectations for improved returns.

This introspection covered the whole airline and ultimately resulted in a program of restructuring and change at the airline to position the airline for its new strategy of pursuing business travellers. One of the change actions was to rejuvenate and realign the Fleet Management Group, in part by the appointment of a new Fleet Management Group Manager who was given the mandate to bring change.

21.1.1 Why rejuvenate and realign?

Such a management call to rejuvenate a unit or group can often be interpreted as there being a fundamental problem with that unit. However, there was no dramatic dis-function or non-conformance with the Group that affected the Group's main focus – maintenance compliance and safety. There had not been any adverse audit findings or other safety-related determinations. Plus, it was felt by the airline's leadership, that the Fleet Management Group was a competent and proficient outfit that complied with its regulatory obligations and its associated procedures with a strong, professional attention to detail.

Yet, there was an issue with expectations, perhaps best described as a 'professional inkling'. Whilst most of the airline was focused around the airline's brand of a high-energy, customer-focused operation, this didn't seem to translate across to the Fleet Management Group. The Group was perceived by the airline's senior leadership team as:

- highly functionally focused, to the detriment of the broader airline
- showing an apathy for the effect of its decisions and approach on the rest of the airline operation (rather than been uncompromising in safety matters, which was acceptable, there was just a lack of commercial awareness across the FMG)
- ripe for improvement to reshape the it into a more sophisticated and integrated enabling force for the company.

To spearhead a change in the Fleet Management Group's demeanour, a new Group Manager with extensive technical, yet engineering and maintenance executive experience was appointed.

21.1.2 Diagnosing the established posture of the Group

One of the new Group Managers' role was to assess and diagnose this senior leadership team 'inkling' and understand just why there was a gap between expectations, performance, and potential capability. The GM diagnosed and characterised much of the Group's disconnect along the lines of organisation alignment and goals. These included:

- Inchoate leadership & organisational tone

- Ambiguous goals & purpose
- Challenging structural dynamics.

21.1.3 Inchoate leadership & organisational tone

In the view of the new Group Manager, the Fleet Management Group exhibited a 'traditional engineering' outfit: an organisation 'stocked' with technical expertise, and being very functionally driven along technical discipline and process lines. The high calibre technical workforce was very conscientious of the safety criticalness of their work which led to a clear focus on the technical tasks at hand. Each unit within the Group performed their specific duties with respect to their training and disciplines with the utmost care; technical excellence was at the core of the FMG culture. However, this led to a Group that was very stove-piped in its operation, with the purpose of the Group's activity somewhat isolated from the broader airline operation.

Context is important. By the point this GM had been appointed, the airline had experienced ten years of significant growth due to market conditions, with little opportunity for consolidation and improvement of the airline's core. Priority had to be placed on ensuring the appropriate certifications and approvals from the NAA were maintained, and that in general, circumstances didn't regress. As such, the Fleet Management Group evolved over those ten years along a 'survival track', only developing structures and processes to ensure their NAA approval was upheld, thus defaulting to strict regulatory compliance and traditional airline engineering structures. There had been little scope, or executive drive, to address a 'next-generation' Fleet Management Group iteration.

Because of this, the GM observed that while the rest of the airline exhibited a strong customer-service focus and ever-innovating ethos, the Fleet Management Group espoused few of these core values. Instead, the prior Group leadership emphasis on just maintaining the status quo was the dominant imperative that still permeated the Group. In the GM's view, this inherently narrow leadership remit did not benefit the broader airline nor the prospects or respect of the Group itself.

This incumbent inchoate leadership milieu incubated several other dominant traits, attitudes and behaviours throughout the Group, including:

- A very limited drive in the Group to ask how the Group could do more or offer more value to the rest of the airline. Instead, an attitude of "I'm doing enough" prevailed.
- Stove pipes within the Group itself was rife with limited cross-functional communication and collaboration
- An environment where much of the technical workforce was disengaged from the operational reality they had influence over, exhibiting a lack of clarity of purpose in their work. In other words, the technical task was the end of their deliberations, rather than actively considering its impact upon the broader airline. Success was seen as accomplishing tasks as defined by procedures, rather than in seeking the success of the broader airline.
- An environment where performance was poorly managed. In the GM's words "there was no difference between achievement and non-achievement".
- A deficit of initiative. Little energy was given to finding ways of improving airline performance, such as schedule reliability due to technical factors, with problem-solving innovations not routinely implemented.

21.1.4 Ambiguous goals & purpose

A glaring consequence of this inchoate management regime was an inadequate alignment between the Group's activities and the goals, imperatives and ethos of the broader airline operation.

Soon after arriving at the company, the GM perceived that there was not a crystal-clear picture in the mind of many of the staff of the value and enabling power that the FMG provided to the airline. The Group was focused on activity, but there seemed to be a disconnect between such activity and the broader context. In the GM's words, "an airline is in the order fulfilment business of moving a guest from point A to point B, but in the Fleet Management Group, an engine was just an engine [rather than an integral component of a transportation service]".

It's likely this disconnect was reinforced by two systematic factors, in addition to a traditional engineering management approach.

First was the way the broader airline operation was measuring the Group's effect. Delays caused by a technical issue, up till that point, were generic, not identifying the 'owner' of technical delay (both the cause, and the unit that could yield influence in avoiding and minimising that delay in the future). As such, technical causes of delays were not examined with energetic levels of rigour, and a consistent drive to improve or fix avoidable issues lacked discipline.

The second was a physical isolation from the Group's 'customer'. This disconnect wasn't helped by the physical isolation of the FMG from EmeraldJet's corporate headquarters (in the CBD), and the airline's home airport[30]. The FMG was located in a hanger on the other side of the airline's home airport, aside from the Maintenance Watch unit (which is embedded in the Operations Control Centre). This physical disconnect meant the Group was not directly exposed on a regular basis to the imperatives that drive the airline. It also set up a situation whereby the Fleet Management Group became a 'hole-in-the-wall' for requests for technical support, rather than as an engaged partner in helping other parts of the airline.

21.1.5 Challenging structural dynamics

Another issue was that of the way the Group was structured, and more specifically, the *dynamics* that structure helped invoke.

As previously mentioned, the stove-piping across the functions resulted in low levels of collaboration, even between the various units within the Group. One manager remarked that the structure made it hard to find a 'logical flow through the Group'. Whilst, as discussed shortly, structural changes were not a large part of the Group's change efforts, some minor tweaking of some of the units helped build focus around responsibility, and not merely similarity of tasks. Greater collaboration with other parts of the airline was also sought to break the 'hole-in-the-wall' approach to engagement.

[30] This may not have been a bad thing as it may have ensured an independence of action on the part of the Group, defusing commercial pressures that might've led to errors or short-cuts. However, it also meant the FMG could easily miss the sense of urgency much of the rest of the airline experienced, and thus not be perceived as a 'team player').

Another factor that the GM observed was the way the 'hands on' component of the Group was both structured and identified. Whilst the formulation, planning, direction and oversight of maintenance activity was as the Fleet Management Group of EmeraldJet, the actual maintenance organisations to carry out the work in the line environment was either a third-party provider or a separately branded line maintenance company owned by EmeraldJet (called *EmeraldTechnik*). The GM identified this discontinuance between the Fleet Management Group and its own 'brethren' in EmeraldTechnik as a subtle barrier that limited collaboration and closer teamwork. The GM noted that it sent a message that there was an 'us-and-them' situation going on, one which also reflected on the Fleet Management Group and its relationship with the rest of the airline.

21.2 The vision thing

21.2.1 Rethinking the Group's purpose

While the Group's technical fundamentals were in good shape, the GM sought to lay down both a challenge and a vision for the reshaping of the group as a more matured and sophisticated fleet Solution provider to the EmeraldJet operation.

21.2.2 Rethinking

As part of this process, the GM set down the challenge of getting his engineering leadership team (unit managers) to think about the positioning of the Group within the airline, and how its role needed to adjust to meet the needs of the airline. It was intended to spark an outward's looking disposition (as opposed to the inherent inwards-looking mentality that had prevailed) and included questions such as:

- What is the role of engineering in the in-service environment?
- How can the engineering function and profession in this environment be more valuable and indispensable to the EmeraldJet operation?
- How can it become a Group whose activities and abilities are more highly prized by the airline's Executive management team?

Posing this challenge set the scene for the GM to outline his vision and direction for the Group to both the management team, as well as the technical workforce.

21.2.3 Revisioning

A fundamental aspect of the GM's vision was about moving the Group from being a technical, discipline-based colony or ivory tower that predominately responded to externally-initiated demands or stimulus, to something else, without neglecting that technical core or dedication to safety, quality and independence.

The GM's vision included the following desired end-states:

- An invigorated, energetic and outwards-focused workforce, operating with pride, ownership and innovation (in accordance with the brand values of the airline)

- A workforce motivated by a common goal and purpose that would drive greater collaboration and coordination, driving the various units to work together closer, rather than act as mere inputs to a bigger unseen process. In other words, a common purpose that facilitates a logical flow through the Group.
- A shared belief that Engineering success would be found in the success of the broader airline operation and expressed in terms of passenger and operator goals:
    - namely safety of operation, reliability and availability of aircraft, on-time flight performance, and best-in-class aircraft cost-of-ownership
- A Group norm of pursuing and implementing innovations that would realise this customer focus
- A more engaged workforce that sought to make a contribution, to collaborate, and to share knowledge for the benefit of the Group, and the airline
- A Group that keeps a keen eye on performance, and would be motivated to do its bit to help deliver
- A Group not being as concerned with maintenance cost as with service performance.
- A Group with high levels of engagement with the rest of the airline operation, working as embedded, integrated partner, and less of a 'hole-in-the-wall'.

This second-last point was raised by the GM as there was still a focus on maintenance cost reduction (one of the few commercial imperatives that did permeate the Group). The GM's view, however, was that such an emphasis was not entirely constructive, saying maintenance costs were "a fact of life". If the Group helped the airline achieve its goals, it became a "self-financing" endeavour anyway (i.e., passengers flown to their destination on-time will fly again with the airline).

In short, the GM's vision was to create a Group that provided a Complex Integrated Solution to the EmeraldJet operation, working to ensure ongoing aircraft availability and readiness. Whilst there was no formal contractual mechanism, a formal delay and performance reporting regime helped isolate instances where Engineering contributed to the success (or failure) of the airline's operation in moving a guest. It was an aspiration similar to the ancient Persian concept of a *vizier* – a deputy in a government whose title literally means 'to bear a burden [211].' A vizier was a trusted advisor who worked behind the scenes to implement the will of the Leader, relieving them of the onerous task of implementing such wishes, whilst also protecting the Leader's interests.

However, whilst there was a significant 'customer focus' of this vision, this vision also called for a Fleet Management Group that maintained its independence of action and decision, and a Group that would not be overruled or overpowered by commercial interests in a way that compromised safety and airworthiness. It was a vision for a Group that had both strong alignment to customer needs, but also for a Group that could make an unabashed 'safety call', even when it threw a proverbial spanner in the works. It was a vision for a Fleet Management Group that was both a provider and a protector.

21.3 Reshaping the Group

21.3.1 Implementing change

It's tempting to think that most change implementation programs – or the visible aspects of ones, at least – involve wholesale changes to the corporate structure. In this instance, there were some structural changes, such as splitting out some roles to make responsibilities clearer. However, the main changes were in new or amended routines, building a sense of Group identity, and driving accountability for performance.

To implement his vision, the Group Manager initiated changes on four key fronts:

- Adjustment to the Group structure
- Closer performance monitoring
- Driving responsibility for outcomes
- Building an integrated Fleet Management Group identity.

This section describes each of the four fronts. However, this case study is about the reasons and expectations on the Fleet Management Group and its functions, rather than on the lessons learnt from implementing changes, or even the success or failure of the changes themselves.

21.3.2 Adjustment to the Group structure

Before the change implementation, the Fleet Management Group's technical responsibilities and operations were overseen and run by the Chief Airworthiness and Maintenance Controller (CAMC), who reported to the Fleet Management Group manager who was responsible for commercial, administrative and resourcing aspect of the technical operation. However, to advance the agenda for taking greater responsibility and initiative, the GM implemented a quasi-matrix structure. Unit managers would now report directly to the Fleet Management Group Manager but were also oversighted from a technical discipline perspective by the CAMC. In turn, the CAMC had two managers – the Fleet Management Group Manager, and the Chief Operating Officer (who was responsible to the NAA for the airline's overall operation).

It's understood such arrangements were not without their issues, given the complexities of reporting to two levels of superiors in the same chain-of-command. However, it was an important step to ensure there was oversight of professional engineering decisions and maintenance actions with discipline-based accountability, but also to give the commercial and pragmatic needs of the airline a voice and energetic representation within the Group.

Some small changes were also made to the structure. Perhaps the most significant were the splitting out of the Technical Support unit from Technical Services. According to the Technical Services unit manager, these two functions are often joined up in airline engineering and maintenance operations. However, they were split out to bring some focus to what were two symbiotic roles given their focus on lending intellectual support and authoritative technical instructions and advice, but operating in different contexts. Technical Support was an operational and implementation support role, whereas Technical Services was focused more on systemic longer-term and policy fleet management matters.

21.3.3 Closer performance monitoring

If there was one readily implementable change the GM sought to introduce, it was a more sophisticated way of monitoring and disseminating performance metrics that Engineering had an influence over. This is not to say there wasn't already a process for gathering such information or analysing it. However, the new GM sought to significantly enhance both the richness of information and the prominence it would play in the routines and life of the FMG.

Previously, the FMG had focused on aircraft reliability metrics, as mandated by the NAA regulations. They were useful in understanding what types of interventions could be initiated to improve technical system reliability (such as newer model parts, improvements as recommended in OEM Service Bulletins or adjusting the maintenance program to replace the part earlier before failure). However, the broader operational airline 'customer' thought far more in terms of schedule adherence, schedule recovery, and from an aircraft perspective, aircraft availability. Until this point, this had not been at the forefront of the Fleet Management Group's collective thinking and modus operandi.

Thus, an updated reporting regime was implemented. It consisted of:

- A weekly Engineering Delay Summary report that was the basis of the weekly Engineering management group meeting
- A weekly delay review and analysis report that focused on each specific delay event as the basis of identifying leading delay causes, and finding means of implementing improvement action
- An 'open recurrent defects' list, updated weekly, to focus the Fleet Management Group on the top technical issues that had been causing issues.

The weekly Delay Summary became the cornerstone of this data-driven approach. It was based on data generated by the OCC Aircraft Movement Controllers and other OCC members. At the core was a system of delay codes – pre-defined reasons behind a delay, including weather, boarding, cleaning, but also specific technical factors. These delay-codes, attached to a data log that also tracks the total delay time due to an event, formed the basis of this Engineering Delay Summary, and included performance for the prior week, including (expressed as a discrete number, as a rate per 1000 flights, and contrasted with a target rate):

- **"Technical>15":** measuring initial delays of more than 15 minutes, as well as cancellations, where Engineering had direct influence over the situation. This included a reliability-related situation or defect, but also logistical factors, including repair times, lack of maintenance personnel, part sourcing (including AOG), or late delivery of documentation to the flight crew. In short, these were delays for which Engineering could be 'charged' with the delay.
- **"E&M>0":** initial delays and cancellations including events where Engineering had a direct and indirect influence over the situation, and which causes a delay of any length. In addition to the above Technical >15 metric, this E&M >0 measure also included factors outside of Engineering's control or influence (but that still has an effect on the flying program, as well as on Engineering's operations). This particularly included in-flight or groun damage to an aircraft.
- Consequential delays with later flights due to the follow-on effect of an initial technical delay
- Air returns and diversions
- Ground returns and aborted takeoffs
- Total cancellations due to technical issues
- Total delay time due to technical issues.

The report also recorded:

- Daily delay count (and related delay reasons)
- Delays by airport (including actual number, the rate, and contrasted with the number of line maintenance staff at that port)
- Delays by aircraft tail number (and subsequent delay reason)
- Avoidable delays by airport (and underlying reason why it could have been avoidable)

- Delays by ATA-chapter (rather than just recording a technical delay code, the delay logs were upgraded to also capture ATA-chapter (the actual technical issue) with a view to identifying major technical delay drivers)
- Dispatch reliability trend over the past 12 months.

In this push for greater transparency, effort was also put into identifying not only actual engineering-related delays but potential delays as well. For example, a flight might have suffered a delay due to a boarding-related matter; however, the boarding delay code masked the fact that maintenance was still rectifying a problem that would have delayed the flight too, except that the time to rectify the technical issue was less than the boarding-related delay.

21.3.4 Driving responsibility for outcomes

Less of an intervention, and more of a management practice, the new GM sought to use this data enriched environment to drive greater responsibility and accountability for airline outcomes and not just engineering activity. In the GM's mind, exposing the Group to the operational 'truth' would help bring focus and guidance, as well as stimulate improvements and enhancements to the level of aircraft availability to the operation. This was also done by setting clear goals that the airline was to strive for in terms of technical performance (e.g., airline dispatch reliability rate, and not just aircraft component reliability), and was the point of discussion at weekly FMG management meetings. For the GM, these data sets were excellent ways of driving accountability with his management team.

One such initiative that this data-driven approach spawned was a new means of managing spare parts at airports. Analysis of the reliability data quickly revealed that a large amount of delay time was been caused due to aircraft lighting issues for which a simple bulb replacement would have had the aircraft dispatched quickly. However, the way the Group's supply unit had been structured, would hold parts at an maintenance bay far away from the terminal area at major airports, and would take precious minutes to find, recover, checkout and send to the gate for changeover. This was after time was taken to diagnose the problem as a bulb issue. In response, the Group formulated a plan to create 'part-vans' – roaming vehicles around EmeraldJet's terminal areas, stocked with the most frequently used change-out parts to save time at the gate. Until this point, the urgency and straight-forwardness of such an approach were not seen or prioritised within the Group.

21.3.5 Building an integrated Fleet Management Group identity

One other major front the GM sought to pursue changes on was that of an integrated Group identity. This so-called 'soft' measure was felt to be important to help reshape the Group into that more sophisticated, adaptive, and outwards-focused outfit that was part of the GM's vision.

One majorly symbolic action was to re-integrate EmeraldTechnik back into the EmeraldJet brand, signalling to both the Group and the broader airline that the Fleet Management Group was one outfit, and as much a part of EmeraldJet as any other part of the company.

Aside from this action, the pursuit of this coherent identity was less of an action, and more of a daily reminder the GM sought to give to his team. Asserting that the Group was an essential part of the airline's success and that to make that happen, the Group had to operate as one outfit was an ongoing prompt to the Group that it needed to cultivate a service mindset and could not rest on just its technical laurels.

21.4 Learning why: Behind the scenes of the case study

To conclude this case study, it's worth reflecting on why the FMG was so traditional (or as this study will refer to it, *conventional*) in its initial approach. They're not strictly observable facts, and perhaps they're more speculation than anything else. However, they do shed light on the cause; useful context particularly for Part V of this report.

Critically, the Group was set up using conventional structures and existing practices in the airline environment. The Group was founded by professionals and managers who had worked for other airlines' engineering departments, and they were simply implementing what they had seen and done before. Also, some of the structure, and much of the process was driven by NAA regulations in the design of the organisation, and NAA oversight drove daily routines to ensure ongoing compliance. Thus, the sense of responsibility for ensuring quality and high technical standards was taken seriously.

However, this pursuit of ongoing regulatory compliance can become a trap as it can become a default mode of thought. It can place regulatory compliance as the key threshold of achievement for a profession, especially one that is very focused on quality, ethics, safety and specification. It potentially leads to a situation where such an imperative restricts the thinking of the engineering and fleet management function and impedes it from asking other fundamental questions, particularly 'how can we be of more value?' As such, this conventional core-reasoning became the default set of organising principles for the FMG.

Less of an issue in this case study, but still worth mentioning, was understanding where the EEF fitted into the broader scheme of meeting a customer's imperative. It's activities, particularly the regimen of controlling Aircraft Technical Management Policy and managing continuing airworthiness, was a higher-order activity. There were complexities and nuances that were not always easy to detect, and visualising the responsibility of airworthiness and availability can be challenging. It can also be challenging when seeking to reconcile airworthiness and safety factors with availability and commercial ones. Being able to manage airworthiness means being aware, mindful and often even being suspicious and untrusting of data presented, all while avoiding having an uncooperative demeanour.

Thus, it's important to not pass 'judgement' on the Fleet Management Group for its prior state – it was remaining true to existing mental models of how fleet management and engineering has conventionally been organised and operated in the airline environment. The GM's change agenda did seek to transform the Group's demeanour from an internally driven department to a key partner who constantly sought how to be a more valuable player for the broader airline. Intriguingly, however, this did not require a fundamental restructure to the Group; rather, it involved setting down new foundations and building new alignment and routines. In short, it was building a new core-reasoning and management methodology.

CHAPTER 22

Five-By-Five

Reflecting on Lessons from the Case Studies

22.0 Learning from the case studies

This Chapter seeks to draw out and quickly characterise some of the key conceptual observations, challenges, and questions from both case studies. It does this to carve out and provide some initial critical reflections on some of the key issues and challenges that face CIS arrangements that necessitate new thinking. This study then takes this summary and builds upon it in later chapters to further examine and put forward new thinking on these matters.

This chapter doesn't list every conceivable issue that faces the Integrated Solutions approach – there are other matters that could be examined, such as market trends, customer uptake of the IS approach, and whether the IS approach does, in fact, provide value-for-money. There are other management challenges, too, such as recruiting and talent management, and ways of how to manage the customer relationship better. These sixteen observations were selected because they stood out not just as distinct observations, but also were conspicuous impressions or fascinating peculiarities that this study feels are worthy of some closer examination in some form. Such curiosity was guided by the overarching research goal of this study – namely generating insights and tenets for a management methodology or logic for Complex Integrated Solutions, and better understanding how the Embedded Engineering Function plays a critical role in the successful execution and delivery of CIS's.

22.1 Observation 1: Sustainment-focused Solutions are much more than just a maintenance business

It's tempting to fall into the trap of focusing on one or two principal activities as being the 'product' offered to a customer – in the instances of the case studies, this is (colloquially) "doing maintenance." However, these case studies are not exclusively of maintenance operations, but of *Integrated Solutions*.

A Solution environment is made of many facets and many different dynamics all happening at once, including the Solution being:

- A business proposition/offering – namely an ongoing value proposition from the Solution provider to the customer
- A service that delivers benefits like a commoditised (namely, a highly repetitive) service, despite the shrouded technical complexity involved. In other words, an expectation by customers of ‘business as usual,' despite there been many unintended implications from simple service or improvement requests.
- The delivery of value that is perceived by people, rather than just the measurement of technical parameters, and therefore open to subjective and irrational definitions of value
- Using assets and equipment that has a changing reliability and predictability profile with the passage of time
- The emergence of new technologies and threats which can render obsolete aspects, if not all, of the aircraft, and hence the need to adapt
- Based on the underlying assumptions of the contract constantly changing and evolving (such as training pilots to progress to a certain front-line fighter type, that changes half-way through the in-service contract)
- A response to a customer imperative to keep pushing the envelope, such as tactics, operational effectiveness, or efficiency, potentially leading to a change in the usage profile of both the aircraft in the air as well as the logistics concept
- An adaptation to new, emerging challenges, whether hazards to the safe operation of the aircraft after the customer seeks to deploy its capability in new and expanding ways (such as new tactics, embodied systems, and in-flight product), or the the political-customer environment changing, such as economic worries putting pressure on budgets, forcing a change to the concept of operations.

A maintenance operation alone is a dynamic environment, where operational tempos, technical issues, and logistics challenges make planning difficult. However, a Complex Integrated Solution takes the dynamic complexity level to a new level. Not only is it dealing with the day-to-day unpredictability of maintenance operations, but it has to balance this also with medium and long-term issues, such as capability enhancements, changes to the customer environment (whether that be political implications, cost constraints, or the threat/competitive environment), and dealing with the complexities of an ever-diverging homogenous aircraft fleet as the fleet ages.

This complexity is then superimposed upon existing organisational complexities. In the Milvus example, the SDG was also engaged in delivering other support contracts. It also required a significant level of technical input from the Milvus’ TDG whilst they considered its own future as an engineering outfit, faced with the prospect of moving to an all-support operation following impending production line closure. And in the instance of EmeraldJet, the ongoing nature of airline operations presented one level of complexity but was also compounded by airline growth (of passenger numbers, flights, fleet size, destinations and aircraft types), as well as corporate aspirations to reposition the airline in the marketplace.

In all, Solutions might appear to present some consistent offer or continuous operation. However, they exist in the context of constant change and complexity, and to equate them as merely a logistical problem of performing maintenance is inaccurate.

22.2 Observation 2: Fleet management Solutions are complex, and have no textbook

Both the Milvus and EmeraldJet Solution operations seemed to be built on the reasonably enunciated core reasoning (including principles, concepts and mental models) of *maintenance management*, a concept likely arrived at[31] due to regulatory requirements, themselves fashioned by decades of experience and accident/incident investigations. In the same vein, however, it became apparent that there was a lack of models, frameworks and set of principles that each organisation could adopt and implement to make their respective fleet Solution operations more cogent, more effective, and more aligned to the customer's persistent problem space. In other words, a management methodology aimed at making sure the Solution continued to remain a valuable partner for the client and not an outdated hindrance.

22.3 Observation 3: Solution design must be predicated on benefits, not just activities

Whilst maintenance activity was an indispensable activity in both case studies, other critical activities had to be executed to ensure Solution success. In both instances, the customer expected a range of other activities, outputs and outcomes, such as logistic support to operational maintenance staff, full engineering support and consultancy for the fleet, an order completion function to ensure aircraft were kitted out and available for the necessary training course the customer is delivering (in the first case study), among other things.

The notion that the solution is merely a highly-tuned maintenance production line is vastly incomplete. Consider that the customer seeks – either explicitly or implicitly – from the Solution:

- **Order fulfilment:** An 'on-demand,' commoditised order fulfilment service. The customer states it needs a certain number of aircraft available with particular reconfigurable equipment to perform an aspect of the training syllabus, or to fly certain routes with the necessary onboard product. The customer expects that such requests be fulfilled in a timely, 'business as usual' fashion, even if there are unintended ripples through the service delivery system from what might appear to be simple requests.
- **Consistency:** A reasonably smooth availability and reliability profile of each of the aircraft assets – despite the scientific ageing process that makes this profile non-linear with time
- **Aircraft Adaption:** A recognition that downstream strategic factors (e.g., a new fighter capability by a geopolitical rival) will ultimately drive changes to the operations model (eg, training program), and that this can require a change in the capabilities of the aircraft. Thus, there must be a recognition that the aircraft design will probably need to be adapted to meet these emerging requirements.
- **Service Evolution:** A recognition of the customer imperative to keep pushing the envelope in terms of tactics, operational effectiveness and efficency, in turn, driving changes in the usage profile of both the aircraft in the air and the logistics/service delivery concept. The same can

[31] The providence of such mental models isn't the aim of this study; merely recognising their existence and incomplete nature in this context.

also be said for a changing political and budgetary climate that may also force a change to the concept of operations. Either way, this requires greater flexibility of the service-delivery organisation to respond to the necessary logistical arrangements, as well as understanding the technical impact a different usage profile brings – on a range of different time horizons.

- **Consistent Safety:** An ongoing and active management of new safety hazards that may emerge from the fleet as the customer expands the way it uses its aircraft.

These expectations point to an Integrated Solution as being far more than a maintenance operation, even though it is a significant activity of the Solution. Ultimately, the Solution is a business proposition – it's a service line to furnish training-ready or route-capable aircraft that the customer needs when they need them. The customer is interested in business outcomes (trained pilots or profitably moved passengers), not technical activities.

The design – or architecting – of the Integrated Solution is more than thrashing out the key points of a contract. It's about being intentional and strategic about how the Solution from the outset will work. This includes defining the relationships between the provider and customer, how the internal delivery structure will be devised, and how the Solution will be a beneficial, enduring deal for both the customer as well as the provider.

It reflects the realistic expectations of the nature of operations to be performed – the tempo, the style to be used, the key relationships and understanding between the two parties about how decisions will be made, and how conflicts will be resolved. Some critical aspects of an CIS design also include just what exactly is being sold, just what exactly the solution is trying to achieve, how all this translates into a viable business model, and how pricing of the solution is determined to convey a sense of value-for-money.

22.4 Observation 4: Solutions need a clearer business model – and subsequent operations model

For a Solution provider, an Integrated Solution isn't just an operation, it's business in its own right. Thus, to fully understand the Solution's design, one must consider the Solution's business model.

A business model "describes the rationale of how an organization creates, delivers, and captures value [212]" – in other words, the underlying logic of how a particular business operates, and how it offers and captures value (i.e., make money). A business model is often pictorially portrayed via the Business Model Canvas (see Figure 68) which draws eight different considerations, including resources, activities, suppliers, customer relationships and segments, distribution channels, costs, and revenue streams, into a central concept of value propositions. These propositions are the offer made to the client, explaining how the business will solve a particular problem of theirs in a cost-effective, competitive and beneficial way.

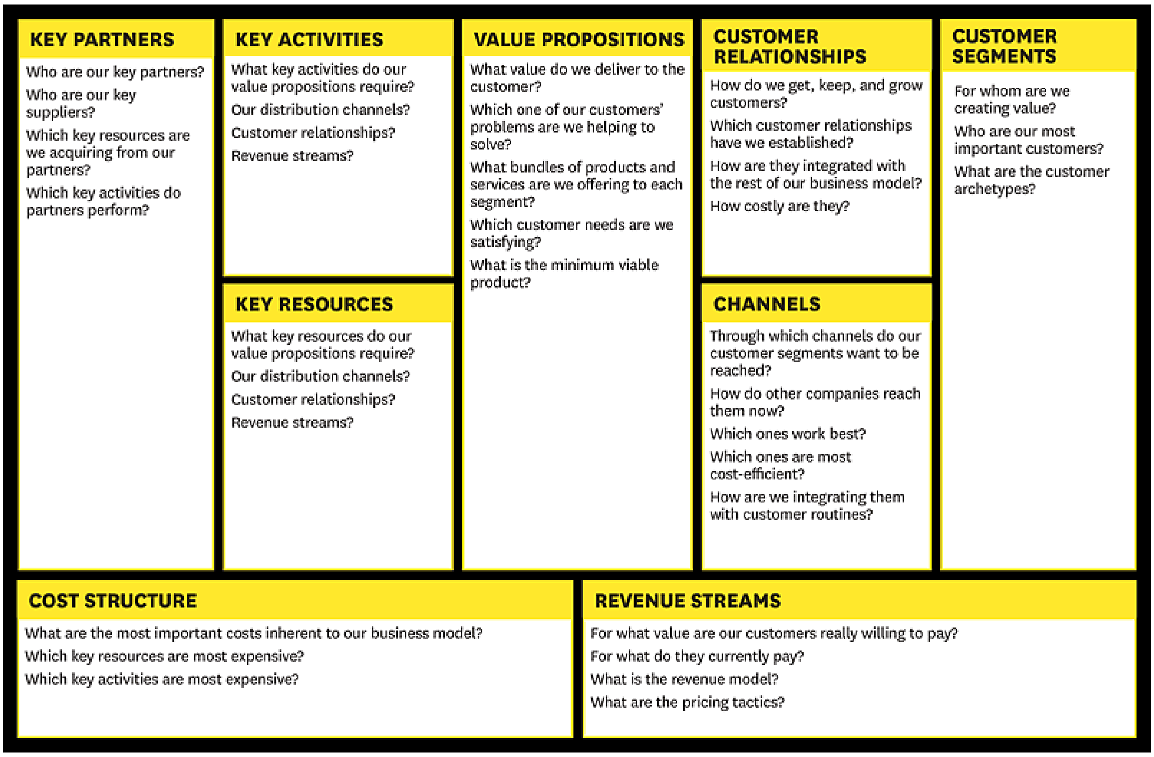

Figure 68: The Business model canvas [212]

Finding the right business model – and subsequent operations model – was a subtle theme that arose particularly within the first case study, although the EmeraldJet case also illustrated a need to reinforce how the Engineering Group helped the rest of the airline (i.e., how it created value). Whilst the customer-facing aspects of the Solution's business model were fairly well articulated and explained, the internal logic inside the solution provider was at times incomplete.

On the surface, the trainer aircraft business model seemed fairly straightforward: timely delivery of aircraft, underpinned by minimum aircraft availability targets, achieved through an engineering, logistics and maintenance operation, offered at a performance-based, fixed price deal. The price of this access to the use of aircraft was agreed up-front, with few surprises, and a pre-agreed set of performance metrics was used to determine if adequate performance had been attained. If it hadn't, an agreed formula was used to deduct payments for non-delivery.

Digging a little deeper, the arrangement with the customer was a bit more complex – for example, the engineering resource level was pre-agreed with the customer, and engineering consulting-style services were pre-ordered and available to the customer as required. This aspect of the Solution was not strictly performance-based but ensured an understanding between the provider and the customer on what was beyond the scope of normal, service-delivery operations. Whilst not as neat, or a 'one-line item' bill as perhaps the term "Integrated Solution" might suggest, the contract did offer a fairly clear and consistent business model insofar as the customer relates to the provider.

22.5 Observation 5: There are enterprise alignment challenges when seeking to capture value from Complex Integrated Solutions

How the CIS provider organised itself to capture value from Complex Integrated Solutions wasn't entirely mature in the first case study. The global Milvus program at the time of the investigation was still highly driven by sales of aircraft, followed by 'traditional' in-service, revenue models, mainly:

- Sale of spare parts (with a catalogue price)
- Modification projects, consisting of engineering hours, plus manufacturing costs, plus manufacturing start-up costs
- Queries & advice, much like a consulting firm, charge by the hour
- Other consulting-style services such as aircraft retirement advice or feasibility studies,
- Subscription and change fees to Technical Publications.

The business model of the DefTech New Aragon Integrated Solution was disadvantaged by a lack of business model alignment with the broader DefTech Global approach. The issue of taking a 'double-margin' did not appear to be resolved (a situation where one part of the company sells a product or service to another part of the company, who then sells to an external customer, but where each transaction contains a profit margin).

It's not an easy issue to resolve. Whilst the SDG delivered most of the Solution for the one fixed price, the Global Milvus Program charged by the volume of activity in most instances. Thus, the SDG had to integrate those prices and costs into its cost structure and held much of the inherent technical risk (apart from component reliability warranty or manufacturing quality warranty) associated with the Milvus. In instances where the aircraft design needed to be rectified for safety or reliability issues, there did not seem to be a clear internal model of who would bare the internal cost, despite DefTech Global, as an enterprise, holding the risk.

This internal customer approach, especially with the Type Design Group within the Milvus Program offering its design support activities as a priced-service (rather than an obligation), offers another quandary. In the first case study, there were instances where the TDG was on the SDG's critical chain and where the TDG's approach was to offer in-depth technical advice, rather than a prompt return-to-service ethos (as was an instance of a fleet grounding). Balancing the need for proper product governance with nimbleness, responsiveness, and adaptability was critical to ensure Solution autonomy (especially given the SDG 'owning' the risk associated with the Solution program) as well as proper safety control and outcomes.

This integration is even more essential given it's the one group of shareholders who own the enterprise that contains both the SDG and the TDG/Milvus program. Finding an approach that offers value to shareholders did not seem mature at the time of the investigation.

22.6 Observation 6: Just who is the customer?

In retail and consumer marketing efforts, it's clear who the customer is – they're an individual. Even with the significant variations in personal tastes, marketers can study different groups of people – *demographics* – to understand their narrower band of tastes, desires, and needs, and can subsequently test satisfaction levels after a product or service has been purchased. While there are significant external factors that can influence a person's buying choices, ultimately the decision maker – and product/service 'experiencer' – is a single unit.

However, in the case studies, the notion of 'customer' presented a more convoluted predicament. While there is the temptation to perceive a customer (such as the NAAF) as a single, homogeneous, unified, and consistent unit – a singular personification of the customer organisation – the reality is a customer organisation can be a complex entity with varied, changing and fickle social and political structures.

In an industrial customer, many people engage with the provider which yields many different experiences, resulting in many opinions (whether they are articulated through the rest of the organisation or not). Whilst there is predominately one ultimate decision maker in an organisation, there is the potential for many opinion influencers – and thus potentially– decision influencers.

In the Milvus case study, there were many facets to the customer organisation. There was the immediate operational customer, the broader Air Force enterprise, the contractual and logistical customer, and the regulator (not necessarily a 'customer', but because in this instance they formed part of the broader Air Force enterprise, whilst part of a separate command structure and independent in its activities, it can't be entirely considered a traditional regulator). This is not to mention the broader Government behemoth that these various customer groups were a part of.

Consider then the various sub-groups that made up these dominant customer groups. The team of full-time instructors, the cadre of students who were spending time with the Squadron for training, the operational maintenance staff who prepared the aircraft for flight, the flight operations planning team and the Squadron command team form the immediate operational customer.

The EmeraldJet example might seem a little more straightforward; however, even it presented complexities. Whether the discussion revolves around a corporate expectation by the airline's senior leadership team, or by an operations controller, or by the in-flight product manager, the notion of who is the customer remains complex. Thus, when comprehending the literally thousands of people this begins to add up to, intelligently identifying who the "customer" indeed takes effort and a different approach.

22.7 Observation 7: Success is not always evaluated by performance

Focusing on what the provider is contractually obligated to deliver is critical. Yet understanding how a customer experiences the Integrated Solution is just as essential to business success. If the customer does not like the overall experience, even if the contract obligations are being met, this can spell bad news for the provider. Providers that were performing well, by the standards set out in the contract, have had their contracts torn up because the customer failed to see value-for-money in the program (something the fault of the customer in their contract negotiations with the provider in that situation from Chapter 2).

Thus, whilst perhaps a contradiction, explicit, contracted performance requirements may not be the only expectations the customer might have on a provider. Often there are tacit, sometimes even unconscious expectations that a customer organisation may have on a provider.

It's an important factor that relates to the previous observation about who is the customer. Understanding how the customer thinks is critical to success, and navigating this complex relational space can help avoid misunderstandings and unfair assessments of provider performance.

22.8 Observation 8: Solutions involve evolving relationships

Given the complexities of the customer environment that lead to constant change, it follows that Solutions require constant evolution, leading to a relationship between provider and customer that passes through seasons. This is exacerbated by the long-term nature of the Solutions posed in the case studies. With the Milvus Solution slated to last for 25 years, there was scope for many changes in relationships between the provider and customer.

Indeed, these relationships can pass through various seasons. Again, from the Milvus case, relations initially started out cold, with customer resistance and hostility quite pronounced. After a while, relations were normalised, but not without their flash moments and periods of concern, before subsuming again. Needless to say, neither the Solution nor the relationship that binds the provider and customer together stays static.

22.9 Observation 9: Solutions are not mass produced

From each of the case studies, the Solutions might appear to have some common characteristics and challenges. However, one lesson that can be drawn from both case studies is that merely rolling out a stock-standard approach to fleet engineering and management was not entirely valuable and ultimately required adaptation.

By their very nature, Solutions are bespoke, tailored schemes that must adapt to the concept of operations of the customer, whether that concept is explicit or not fully stated. This is not just the concept of how the aircraft or system will be used in service (e.g., a mission profile), but the routines and practise of the customer organisation.

Whether that means constructing a Solution for an airline that is engaged in aggressive growth, or one that is holding its market share steady but with many foreign and isolated domestic ports that presents extra logistical challenges, or for and Air Force who engage in extensive expeditionary operations, or who are based from just the one location – devising a Solution must consider the unique challenges and specific nuances of each operation. Similar elements may be common, but a ‘cookie-cutter’ approach is not Solution at all – rather it’s a commoditised service program.

22.10 Observation 10: “If schedule is King, then airworthiness is God.”

A major and key theme that came through consistently was the absolute importance of keeping aircraft airworthiness and safety imperatives distinct and somewhat separate from schedule and commercial pressures. Completely independent and aloof was impractical, but that tension between airworthiness-versus-cost, safety-versus-schedule, and protection-versus-production had to be actively and closely managed.

From the case studies, this was managed through governance structures, work processes, and even the physical layout of some buildings. For instance, the maintenance management part of the SDG was physically separated from the project management team with a glass door – not much in itself, but it had been recognised by staff as acting as a separation between the service-delivery focus of the project team, and the control of product safety.

Of course, it’s not a unique situation – airlines have to deal on a daily basis with these contrasting forces (although they can also be compatible forces – the same activities that make an aircraft airworthy can make it more reliable too, for example). Where an integrated solutions approach adds complexity is the sharing of operational imperatives across organisational and enterprise bounds, and in particular, the explicit performance goals that are inclined to induce behaviours that favour schedule over safety – assuming there’s no organisational self-restraint.

For instance, an airline’s maintenance group will feel the ‘squeeze’ to meet given schedules to ensure aircraft fly their timetabled routes. Operations staff will be on the phone to maintenance staff, ‘breathing down their neck’. There is a cultural dimension that is at play – the maintenance group is “part of us,” they wear the same logo or uniform, and are likely to feel the force of customer backlash when they get in wrong. They are also unlikely to face an explicit penalty for the untimely availability of aircraft since they are ‘part of the family.'

With an Integrated Solution approach, however, there are two different, distinct, and separate organisational entities – along with their respective identities and cultures. Suddenly, it’s not just pressure from the flight operations customer that must be considered; there is an explicit, persistent, and quantified price of failure. And for any business owner, that price is stated in the language they speak the most – money.

While there was no evidence to suggest in the case studies that this was an issue – indeed, there appeared to be great steps taken to avoid such weaknesses – there exist preconditions that can enhance the already systemic temptation to advance schedule and commercial interests over safety ones. If these increased temptations are not understood, appreciated and actively managed, they could form a weakness in the system of defences against a negative safety condition.

22.11 Observation 11: Managing 'ageing' aircraft will affect Solution providers

Perhaps more an observation from the first case study, although one that will also present some challenges for the EmeraldJet study too, is the issue of 'ageing aircraft.' It's become a major topic in recent years as customers seek to extend the life of well-used aircraft assets beyond their envisaged lifetime and attempt to keep the intensive effort required to a justifiable level.

A significant challenge for the CIS approach is how the service provider seeks to:

- Predict and budget for the costs that are likely to be incurred through the life of the CIS program
- Work to match customer expectations of the price of the solution with the actual cost drivers (especially in latter stages of the solution's life). This involves customer relationship and political management capabilities as substantial price rises into the future – assuming that's the pricing strategy – can cause some suspicions within the customer organisation about been 'ripped off.'
- Deal with the potential for changing expectations concerning safety standards. Whilst the standard to which the aircraft was originally certified generally stands true, any customer or regulator demand for aspects of the aircraft to meet a contemporary standard needs to be monitored, and who is obligated to pay needs to be clearly articulated. Where the CIS is sustaining an older design (not just airframe), they would likely have been certified to an older (sometimes a less demanding) standard. This may be at odds with customer expectations of a higher standard. Crashworthiness and survivability would be one example of such a mismatch.
- Be alert for safety 'unknown unknowns'. Even well qualified and well-utilised aircraft can have hidden unsafe conditions, whether due to modifications, or existing from the very first iteration/model of the type. The Nimrod accident of 2006 is a case in point [207]. The IS provider, through its partners, needs to be vigilant until the day the aircraft is removed from service for signs of such latent unsafe conditions.

22.12 Observation 12: Identifying the engineering function isn't always straight forward

Trying to draw a circle around what is Engineering in such an in-service context was not a straightforward exercise for either case study. Just because an organisational unit was designated as 'Engineering' did not mean that unit actually contained any professional engineering oversight or direction. As previously alluded to, the term 'engineering' can be technically misused for non-professional pursuits, such to describe the activity of technical trades.

Going further still, some distinctions need to be drawn between other expressions of engineering, including:

- An engineering enterprise (a Company whose core business activity is engineering)

- An engineering organisation or function within an enterprise (represented by the formal bounds that are put in place for good engineering governance), whether organised as a division or with some sort of 'Chief Engineer' for all of the company's engineering units
- An engineering team being an organisational unit devoted to some engineering task or activity
- An engineering project or program, similar to an engineering team, but focused around a particular product or goal (e.g., a bridge project, or the 787 program).

As described in Chapter 6, there are other manifestations of engineering (from a more ontological perspective); the above is more how engineering is organised and deployed in a real-life corporate structure. Appreciating the nuances and differences in how "engineering" is used is useful to understand the true nature of what is been described. This is particularly found in the case of DefTech Global; whilst it might be described as an engineering enterprise, their core business activities and core competency go beyond engineering into project management, logistics, maintenance, manufacturing, and flying operations. In the instance of the Milvus, these various elements were brought together into a service offering that delivered flight hours for the customer. Understanding the pedigree and capability of the company helps build proper contextual awareness.

22.13 Observation 13: Professional engineers play a sentinel role in in-service Solutions

Fleet management or support-enabled Solutions that are highly technical clearly require some level of professional engineering input and 'leadership' (from a discipline and product governance perspective at least). Both case studies reveal a pattern whereby the Solution provider operates on three levels of engineering disposition, as reflected in Figure 69.

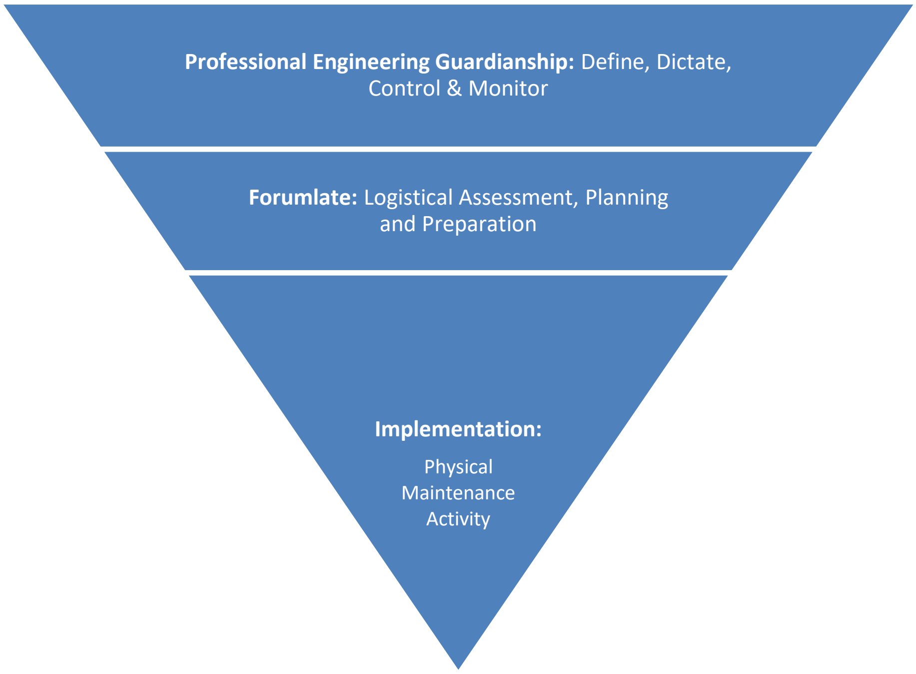

Figure 69: The Engineering Community and its various responsibilities, and disciplinary-directed by a professional engineering staff

Much of the Solution provider's organisation is either involved in formulating maintenance activity – planning, coordinating, or advising – or implementing maintenance instructions as defined by a professional engineering post. The actual intellectual work of problem-solving and 'heavy' professional engineering consideration and analysis and work are vital. However, understanding the interrelationships of these different responsibilities is important to understand how an engineering community is professionally led and guided by professional engineers, but applied and implemented by other technically-aware tradespeople and professionals in a practical and physical manner.

22.14 Observation 14: Engineering in the in-service environment isn't always traditional technical work

An interesting point observed in both case studies was that the EEFs, whilst focused on ensuring technical integrity of the aircraft fleet, were not constrained to using engineering design to solve problems. Their primary goal was not using engineering as an end in itself but was rather focused on providing a fleet of airworthy aircraft in an availability-driven environment, using any means it had at its disposal.

It's a cognitive process similar to what is described in the HRO concept explained in Chapter 11 – working in an inherently hazardous environment fraught with risk and danger, but safety is not the only outcome. Providing the benefit of that operation (whether nuclear power, ATC, or aircraft carrier operations) is the ultimate goal, but with unassailable priority also on providing it safely.

Technical solutions may not have been technically elegant, but yielded the desired effect. It's a disposition with a certain amount of 'just do it' flair about it; if it can be done safely, it is better to put an aircraft on the flight-line, meeting the availability requirement, than to have an elegantly-crafted solution embodied on the aircraft, but having that fleet unavailable for weeks or even months. The immediate benefit to the customer wins out over the need to have a technical purity.

Further, a striking observation from the case studies was a deeply-held responsibility for the fleet's which they oversaw. This included the monitoring and assessing of all faults, issues, and hazards associated with the aircraft, but looked not only to the rectification of the problem (e.g., repair) but also to the root cause. To discharge this transcendent responsibility, the EEFs would investigate and implement solutions along with many non-technical or non-scientific lines, including:

- Is there a sufficient level of training?
- Do the manuals contain a sufficient level of information?
- Is there an appropriate level of preventative maintenance, or should there be more?

It's extensive, perhaps even diverging role, that isn't focused on *building* something, but *attaining* something.

22.15 Observation 15: Engineering plays a critical role in longer-term Solution success

Of course, an inefficient workaround, such as changing out systems more regularly, is not an ideal long-term fix. Whilst the need for daily availability is consistently on the mind of the Engineering functions (and Solution provider organisations) in the case studies, being able to provide this availability in the most cost-effective manner is crucial. It is here that the Embedded Engineering Function must engage in what might be termed a two-speed, or even three-speed operation. Whilst there is an almost frantic effort to ensure daily fleet performance, there is also the need for teams to work towards finding long-term solutions to issues that arise.

It's here the EEF cannot afford to be a passive bystander, but rather adopt an 'integrator' mentality. Such a mentality is where the EEF seeks to address issues on multiple fronts, and across several time horizons (such as weekly, yearly, and on a more strategic, longer-term basis).

22.16 Observation 16: Product-centric definitions of engineering don't cut it

In the context of the case studies, not only was it challenging to draw a line around the organisational units engaged in engineering, it was made more difficult by the narrow definitions of engineering that really didn't explain engineering's role in the in-service environment. Also, dominant engineering management frameworks, such as the traditional systems engineering lifecycle – a bedrock of much engineering thought – added little value to understanding the in-service aspect of a system's life, let alone providing a useful framework for Complex Integrated Solutions.

It does, then, raise the question: if engineering in the in-service environment isn't about designing and manufacturing things, then what is it truly concerned with?

22.17 From learning to reconceptualising

Whilst these observations are perhaps revealing and better portray some of the challenges and gaps in thinking around Complex Integrated Solutions and the role that engineering plays, there remains two questions:

- So what?
- Where to from here?

It's important to firstly remember that many, many more challenges could be raised from reflecting on the case studies, including better understanding an operations model for Solutions, to organisational design of Solution delivery units, to devising better global product governance frameworks. These are important facets that are worthy of further thought and attention in their own right. However, this study seeks to use these observations as the basis for generating more refined and nuanced thinking and principles for Complex Integrated Solutions and the EEFs that empower them.

This chapter has been a transition piece from real-life examples and challenges of Complex Integrated Solutions, to several chapters devoted to further examination of these key themes while also presenting new thinking aimed at better informing a CIS management methodology. This will be done on several fronts:

- **Principles and tenets squared at building a new logic around CIS:** Despite the definitions and characterisations of Integrated Solutions in chapter 7, how can Complex Integrated Solutions be better characterised? What are some of the nuances, characteristics, traits and overall nature of CIS's? What are some of the 'unwritten' rules of the game that seem to define, drive and distinguish CIS's from other major forms of business? What are some of the demands a CIS places on a Solution provider? What is a new logic that distinguishes CIS's from traditional, product-driven business activities that OEMs and other firms might be engaged in?
- **Consider what is unique about engineering in the in-service environment:** What are some of its major considerations and drivers? Whilst it has been a practise in some form for some decades, what are some of the key responsibilities and work methodologies?
- **Observations and presentation of a reconceptualization of Engineering:** to better encapsulate some of the unique characteristics of in-service engineering activities
- **A reflection and reconceptualization on Airworthiness Management:** particularly creating some thought-principles to better articulate with cut-through force how to understand and navigate through the often-obscure domain of airworthiness management
- **Articulating a new archetype of a CIS-driven EEF:** What seed-principles should be considered in developing and managing an EEF to create a more cogent, integrated, unencumbered and 'CIS-ready' outfit?

It's on these five facets that this study seeks to contribute fresh thinking aimed at helping managers and staff find their way through in a CIS environment. Why? Because it's an environment that, from observation and experience during the research process, quickly exhibited surprisingly vague and obscure tendencies, owing to the unique nuances of that business activity typology.

Part IV

Business not-as-usual

CHAPTER 23

Forming a New Logic about Complex Integrated Solutions

Ten Core Thoughts for the CIS Typology

23.0 Finding new ideas to organise by

Complex Integrated Solutions represent a unique business activity typology – particularly for aerospace and defence firms who are so often steeped in traditional manufacturing paradigms. Thus, at the heart of this study is a search for some logic – a worldview – that helps better explain the nature of Complex Integrated Solutions, and how to better manage them. It's a quest fuelled by the human desire for a sense of orderliness and pattern-finding – that there's a 'right way' of doing something. Weick and Sutcliff put this desire this way: "Expectations are built into organizational roles, routines, and strategies. These expectations create the order-lines and predictability that we count on when we organise [54]."

So what are some fundamental insights that can be drawn from the case studies about Complex Integrated Solutions, particularly those with an active fleet management and sustainment emphasis? This is the focus of this chapter. In it, this study presents ten core thoughts that help fashion a system-of-logic for Solutions that can be used to generate a more nuanced management methodology. Indeed, these next two chapters form the majority of this study's contribution to an overall CIS management methodology (with Part V focused on a more detailed facet of such a methodology – the role of professional engineering).

23.1 Core Thought 1: What Solutions aren't

Whilst this study has argued on several occasions that Solutions are a unique business activity typology, examining what CISs are *not* is an illustrative way to begin considering the traits, characteristics, and nature of CIS's in a more finessed way. This study identifies four key points of what a CIS is not:

- **A marketing term:** While 'integrated solutions' is used as a marketing term, there is a distinct business model and operating concept that distinguishes this business activity typology from others. It's a typology that goes by many terms and brand-names – however, this does not remove the fact this concept is indeed real and distinct.

- **Re-bundling existing products & services as a 'tailored approach':** It would be easy for business development managers see 'Integrated Solutions' as a *tailored proposal* of their firms' existing suite of products or services bundled together for a unique price. However, this isn't a unique integration of elements not previously brought together in that configuration or arrangement.
- **A 'hole-in-the-wall' transaction or service program:** Complex Integrated Solutions are not input-output arrangements, whereby a customer prompts a demand, and the service provider delivers a service output. Some component repair services often provide such service programs whereby defective or time-expired components are sent to a repair provider, who in turn dispatch a serviceable unit. These are still very valuable service programs – however, they require the customer to plug into the provider's service program, rather than have a product or service system built around their unique needs. While there might be dispensary elements to a CIS, the concept is marked by a *collaboration* with the customer, not just *cooperation*.
- **Commoditised programs:** In a similar vein to the above, Complex Integrated Solutions are not standardised service offerings offered for mass consumption but where the customer must fit their business into the constraints of the offered service package. They may have the potential to look like integrated solutions as they can be quite innovative and occupy a unique position in the market. They are legitimate service programs – they're just not Complex Integrated Solutions.

So, with that in mind, what are some fundamental properties that better articulate the nature of Solutions?

23.2 Core Thought 2: Solutions are built around a customer imperative

Solutions are not just 'customer focused' – they are literally, intentionally and specifically designed and implemented around a customer. They're truly 'customer centric.'

This is generally in the form of standing up some sort of Solution Delivery Unit or Group. It will likely be composed of various, replicable service and technical capabilities – however, they're not a carbon copy of other Units that might exist across the broader company. The Group or Unit is not an out-of-the-box organisation/system that is generically 'attuned to customer needs' – each Unit of Group is stood up specific to that Solution and that customer.

This may include factors such as being co-located or physically close the customer organisation (as opposed to the manufacturer's/provider's core facilities; using customer IT tools, networks and standards where essential; using customer adopted standards; even using phraseology that the customer prefers to use. This is in addition to the core facets of the Solution, such as key metrics, concept-of-operations, and allocation of responsibilities. Such Solution Delivery Groups might be in the form of a business unit of the manufacturer/Solution provider, but they are ultimately *customer intermeshing*.

However, this study would also assert that Solutions are not just built around the footprint of the customer's organisation – crudely, the 'physical' and literal aspects such as the infrastructure, systems, and structure. They're more accurately described as been built around a *customer imperative(s)*.

This is a little more conceptual, as imperatives are not always clearly seen. However, they are of critical importance for an organisation – whether for achieving success and making progress or for fending off threats and risks to ensure organisational survival and longevity. They are pressing matters that require strategic attention, extensive insight and masterful management. Inadequate management of organisational imperatives will lead to downfall.

Thus, building a Solution around a customer imperative is a specialised capability and one that requires far greater integration of the Solution provider with the customer. Solution Delivery Units form a fundamental piece or input to a customer's business operations. Those elements are an essential part of the customer's business and without them will very quickly grind to a halt. Further, in the instance of the case studies looked at, if the CIS provider fails in aspects of its efforts, it can literally be catastrophic – for aviators and the organisation.

It's this concept of a customer imperative that also helps distinguish Complex Integrated Solutions from other service programs. If the Solution provider's efforts were not so critical, these activities could be viewed as inputs from a supplier – smaller elements that the customer could source and integrate from other suppliers.

This notion of 'building around' does raise the question – how do does one describe a Solution? It's not a transaction, its collaboration – a point considered shortly.

23.2.1 Capability generation is an example of such imperative

To further expand on this notion of imperative, Figure 70 presents a mission generation model that highlights one aspect of a customer's imperative – sortie generation or flight operations. It's particularly military focused, although comparisons could also be made for civilian flight operations.

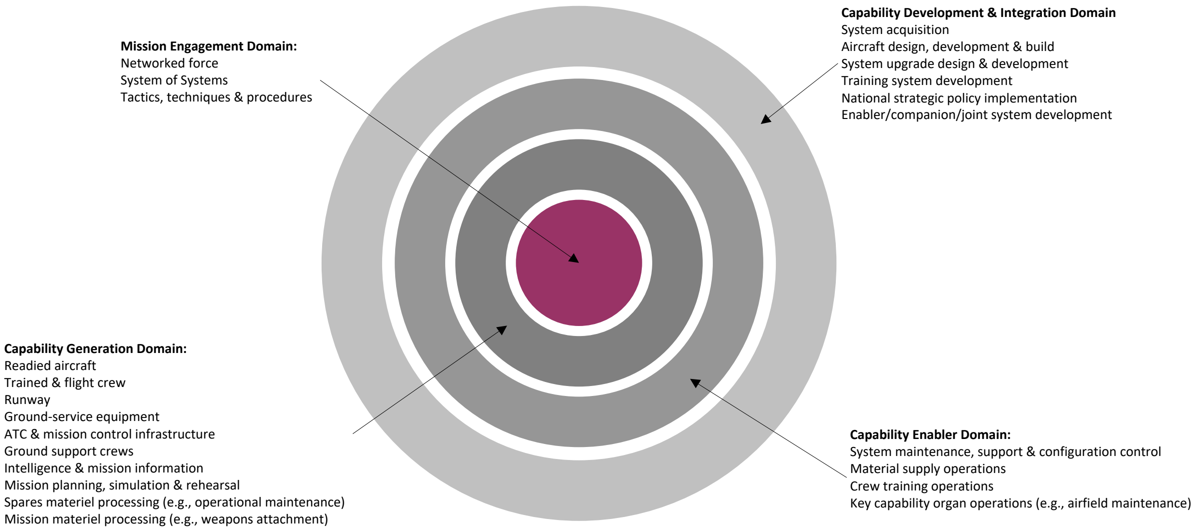

Figure 70: Mission capability generation model

It’s made up of four key domains:

- Mission Engagement domain
- Capability Generation domain
- Capability Enabler domain
- Capability Development & Integration domain.

23.2.1.1 Mission engagement domain

This is the actual fielding of the capability to generate and perform a certain mission – for example, the deployment of a surveillance system (aircraft) to monitor a national border. The other three domains are quite physically definable (e.g., aircraft, support facility, runway, etc.), in this domain the major element (i.e., capability) is more conceptual rather than physical. It relates to the deployment of a capacity to act out in the field (i.e., mobility). This capability is the culmination of the different inputs to create the capability and is not just the deployment of a system. It includes the trained crew, the tactics & rules of engagement, and the use of sensors and other equipment for a purpose. It is also in this zone that the concept of networked operations (and not just infrastructure) becomes apparent. In the case of a Homeland Security application, a patrol aircraft will be operating with other capabilities (such as ground-based interception, investigation, & law-enforcement teams) towards a common security goal.

23.2.1.2 Capability generation domain

This domain deals with the different components that work together to make up the capability to execute a mission. They include (but are not limited to) the aircraft itself (airworthy, available and ready for mission preparation), a trained and ready flight crew, mission preparation activities (such as fuelling; weapon/payload loading; operational maintenance; mission planning, simulation & rehearsal; intelligence processing; weather forecasting), facilities (airfield, ground equipment, supplies), and airfield terminal control/ground-based Command & Control infrastructure. These are the activities, functions and infrastructure that deliver capability into a field of operations. Whilst none of these elements are at the ‘front line’ on their own, they prepare other elements, or work together in order to deliver an in-field capability.

23.2.1.3 Capability enabler domain

The enabler domain lends assistance to the capability-generation domain to ensure its readiness, reliability, and success. This is certainly seen with the aircraft example – the heavy maintenance checks, review of reliability data, and restoration of aircraft reliability is vital to ensuring that a fleet of aircraft is available for a mission. It is also seen with, for example, operational/line maintenance. Supply support is essential to provide some of the smaller items (such as approved lubricants, or Line Replaceable Units) to operational maintenance teams in a timely manner in order to ensure that aircraft can be dispatched on time. This Enabler domain also applies to the training of flight & ground crews, management and maintenance of ground-based assets (such as runways, communications & navigation equipment), and the maintenance of any other ground-support equipment.

23.2.1.4 Capability development & integration domain

Whilst not actively involved in the detail of flight operations, this domain is effectively a strategic layer in the generation of a mission capability. It is the deep-level thinking, analysis and planning that ensures an airborne capability can be actually fielded.

One significant aspect of this domain is the development and acquisition of the complex systems, including aircraft that are essential to capability generation. However, it's not just physical or software systems that exist at this level; rather, other conceptual considerations are foundational, too, including:

- Operator doctrine and high-level standards that feed into training programs
- 'Force-design' efforts that seek to find unique and iterative ways of generating innovative capabilities, even with the same equipment (but deployed differently, such as different tactics, or ways of working with other military capabilities to generate a unique effect)

23.2.1.5 A comprehensive model?

The model does not show any time or lifecycle relationships with the functions described. It also does not show the complex interactions between these activities, and between the different domains (including feedback loops). In addition, it doesn't fully expound what can be meant by a 'customer imperative'.

However, it does give an indication of the 'logistics track' towards an 'organ of capability' (discussed in subsequent chapters). Behind the visible aspects of flight operations (i.e., flight and the mission) is a significant amount of activity to get the aircraft airborne and functioning in the mission environment.

23.3 Core Thought 3: Solutions are realised as ecosystems

Now that the idea of CIS as being built around a customer imperative has been established, how does one grasp and describe a Solution? How might a provider and a customer view this 'thing,' this collaboration, this whole arrangement called a Complex Integrated Solution?

Each 'side' will see something different. A provider will likely see the scheme as a service program to be delivered through a business unit. A customer will likely see them as a supplier or provider – an input to their business, as a *contractor* or preferably as a *partner*. Yet this terminology is perhaps not instructive to understand the true nature of a Solution. For that reason, this study establishes the description that Complex Integrated Solutions are *ecosystems*.

Or more specifically, *Solutions are ecosystems build around a customer imperative*.

An ecosystem is a "system, or a group of interconnected elements, formed by the interaction of a community of organisms with their environment [213]." Thus, it is a useful simile and concept that reflects some of the core traits of a Solution. It reflects some of the 'hard edged' facets – systems, platforms, products and advanced technological aspects – but combines this with the more 'ecological,' human-faceted, organisational aspects that greatly help meet the customer iterative (the 'product-service system' concept). This includes features where a Solution is:

- **A Focused Community:** It's a community of people working together towards a common goal (or whose goals, at least, strongly overlap), even though made of up people from different organisations and stakeholders.
- **A Space:** A scheme with many constituents that inter-relate in a 'trusted space' – an organisational, operational and social 'sense of place' where this community can collaborate and work together to achieve the goals of the Solution
- **A Service Environment:** A Solution is ultimately a service environment in which people, through relationships, achieve business outcomes, and is not merely composed of technology and procedures. There is order, structure, and sequence that aids the 'organic,' people-driven nature of a Solution.
- **A Life of its Own:** The Solution is a dynamic and living 'thing' that morphs throughout its life. It's a hive of directed and focused activity, and not an inert, mechanistic scheme
- **A Shared Identity:** Solutions provide a means of shared identity for the endeavour and the imperative it seeks to meet. Product and standardised service-lines are readily 'brand-able' and thus can create a shared sense of identity and professional belonging (eg, "I'm part of the B737 program"). Recognising a Solution as an ecosystem can help establish a sense of shared identity by providing a mental place-holder (e.g., "I belong to the Hercules Integrated Operational Support (HIOS) program"), rather than a more vague sense of belonging and focus (e.g., "I belong to the support business unit").

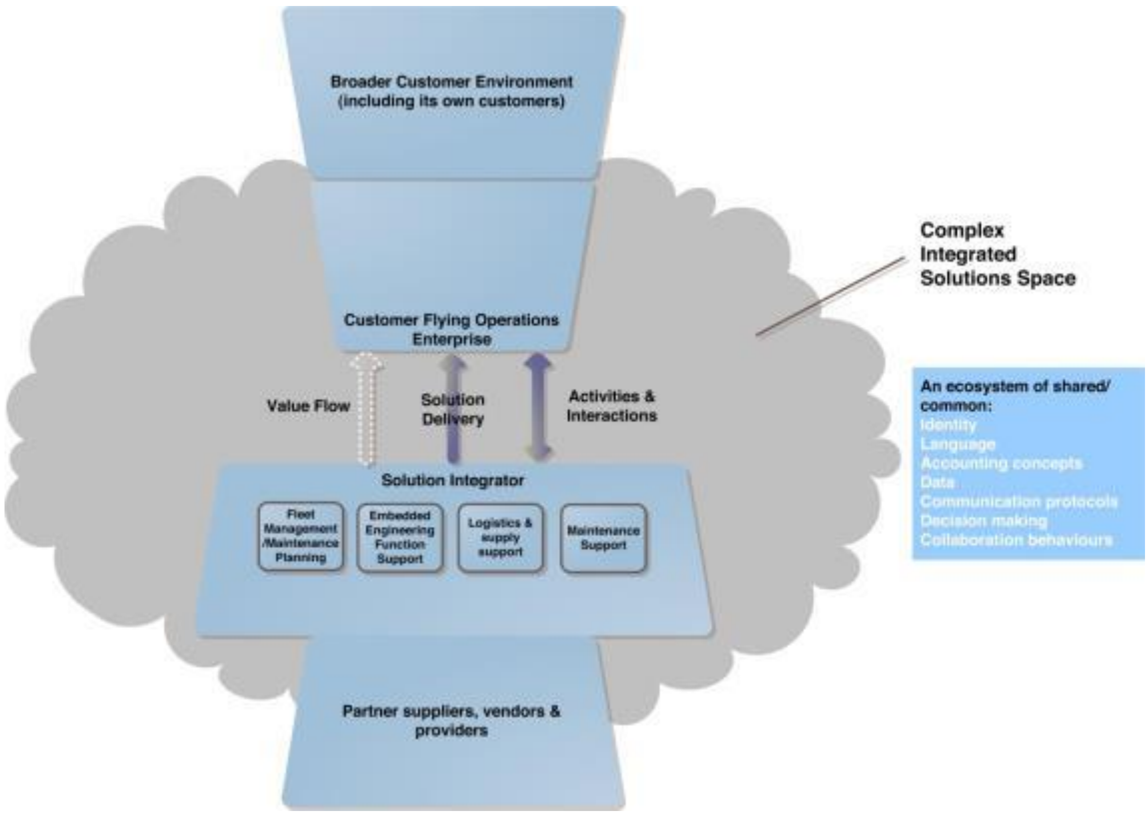

Figure 71: The Integrated Solutions space/ecosystem

More practically, the term *ecosystem* is a useful term to assemble under one banner other traits of this Solution community. These include:

- **Clear boundaries, yet strong relationships:** This ecosystem 'community' is derived from strong relationships among people from different organisations seeking to achieve Solution goals – mostly the customer and provider, but also other stakeholders, such as the provider's supply/support chain, regulators, and the customer's customer. In the case of the customer-provider relationship, it is perhaps better characterised as more than 'customer focused' or 'customer facing', but rather 'customer intermeshing'. In some respects, this Solution community might resemble more of a 'virtual Joint Venture.'
- **Common language:** Where a Solution provider might have a company-wide term for a technical report, in an ecosystem, there is an agreed terminology (that's most likely to align with the customer's common terminology) to describe key concepts and aspects of everyday business.
- **Common accounting concepts:** Whilst not all aspects of the Solutions financial arrangements may be exactly the same, there will be some commonality between the customer and the provider's methods for cost accounting, ways of valuing assets and services, cost modelling and key cost item descriptions. This facilitates a common conversation on costs, prices, and potential cost-reduction exercises.
- **Shared data:** The Solution ecosystem acts as a defined, qualified and trusted community where data is shared for the benefit of achieving the goals and narrative of the Solution ecosystem (e.g., availability, cost reduction, operational effectiveness)
- **Defined collaborations and communication:** Effectively, what's considered joint decision making, and what's not.

23.3.1 So what?

The expression that an Integrated Solution has "gone live" is a statement saying the ecosystem – the community focused on the customer imperative – has been formed, has generated a working capacity, and is now requiring upkeep. This then becomes an implication for Solution leadership, those who hold positions of management and leadership in this unique environment of shared interests. This field of *Solution Leadership* is one not explored in this study, but would be certainly worth a close examination.

23.4 Core Thought 4: Solutions seek to enhance customer condition

Ideally, a decision by a customer to outsource an important part of its business operations is not taken lightly. There needs to be a serious business case whereby they gain some benefit from the arrangement. This study contends that one of those benefits can where the Solution enhances the customer's state.

Consider the primary case study. The critical imperative and core business for the customer was the development of 'tomorrow's airborne warriors' via highly realistic and immersive training, and developing a learning environment that utilised highly accurate training aids and information. Prior to the changeover to the Milvus, the customer engaged in the 'warrior development' business, plus the aircraft maintenance and upkeep business. This meant that the customer organisation's leadership had to actively manage complex issues across two key fronts, potentially drawing their devoted attention away from their core training business onto managing the complicated business sustainment as well.

With the changeover to the new Milvus-based Integrated Solution type, the NAAF was presented with the opportunity to step-back from the peripheral business of aircraft maintenance and support, and instead, shift its organisational 'centre-of-gravity' towards pilot training and development. The Service Delivery Group provided the ongoing upkeep of the systems involved, as well as the necessary logistical and intellectual support to not only sustain the status quo, but to give the customer an innovative edge and 'push the envelope.' Thus, the Solution represented a contractual arrangement that freed up the customer's resources and attention to focus on and enhance their core business.

It's in this vein that this study asserts that Solutions seek to help enhance (or at the very least, sustain) a customer's condition – whether in steady-state operations ('business as normal'), or in an transient, surge state (abnormal and demanding-above-normal effort).

Figure 72: Enhanced customer condition as affected by a Solution operation

It does not have to achieve this by helping the customer with their core business (in the above case, assist with improving pedagogy techniques or enhancements to the overall learning environment). However, the effect the Solution provider has on the customer is far more than delivering something – it goes to stabilising and enhancing their customer's capacity to perform their core business. A Solution becomes an instrument, or at least an opportunity, of business transformation.

23.5 Core Thought 5: Solution success is in the narrative, not just the metrics

23.5.1 Metrics are just part of the story

Whilst metrics provide a yardstick to measure performance, do they articulate a complete picture of success? This is a space that's ripe for further thought and research – namely, understanding how to truly measure what success looks like, rather than the mere compliance with a pre-set obligation that may (or may not) be essential. This was seen in both case studies where the metrics and success parameters changed as the customer learned more about what was important to it.

Further, even with well-set metrics, it was clear from both case studies that many other service delivery modes were also important, even if there were no 'headline metrics' attached to them.

23.5.2 Expecting satisfaction

If one makes the reasonable assumption that 'success' is, at least in part, defined by customer 'satisfaction,' then this concept of satisfaction must be better understood. Whilst metricised measures of 'satisfaction' can be pursued, it is not a static phenomenon. As such, this study makes the following assertions:

- Satisfaction, in the context of a customer organisation, is a complex and dynamic social construct
- The contract isn't the only expressed benchmark of satisfaction or success
- Satisfaction pertains to expectations – whether explicit or implicit – and whether these are met
- Satisfaction is based on how the Solution is *experienced*
- Each Solution ecosystem has a narrative that emerges (but is influence-able)
- Satisfaction is 'measurable' by the 'narrative' that emerges in the Solution ecosystem (and beyond).

23.5.3 What's being paid for?

The notion of *experience* is susceptible to a bad rap in the industrial context – potentially being seen as a 'marketing buzzword' associated with personal feelings of euphoric or epicurean nature. However, how a Solution is experienced is a real phenomenon.

Consider such experiential traits that customer would hope to 'enjoy':

- **Smoothness:** demand-driven outputs are delivered seamlessly and without complications
- **Predictability & Reliability:** that programmed deliverables and activities will happen with great levels of predictability and consistency, and without having to check-up on the provider. 'Guaranteed performance' doesn't just mean there's a recourse for poor performance, but that the provider is highly dependable.
- **Ease & effortlessness:** Push-back is minimal. A sense of a partner who is easy to work with and is cooperative in nature – a partner that actively, and without been asked, works in the interests of the organisation (and their customer).
- **The sense of being 'supported':** A dependable partner who can be fallen back upon, in whom there is confidence they can solve problems quickly, and find workarounds to unexpected issues. There's a trust that the provider can arrest an issue quickly.
- **Flexibility & adaptability:** where the provider has the capacity to change as the imperative changes, either by evolution or by revolution. This includes a capacity for innovation and driving improvements and efficiencies
- **Assurance:** A confidence that the 'product' is high quality and meets a consistently high level of safety and protection

These are characteristics that are felt in the mind. They are 'noetic parameters.'

23.5.4 The narrative

They are also parameters which contribute to a complex social construct called *narrative* [214]. Whilst *narrative* is used extensively in marketing contexts, it's a useful term to capture the essence that 'metrics don't tell the whole story.'

A narrative is a storyline – with past, present, but also future elements to it – abstracted from the context by a group of people who interact and ultimately share that storyline among each other. It's a complex process, depending on many factors, such as social power structures, perceptions, and past experiences, but is part of the cultural fabric of some social entity (e.g., a company, a city, a nation).

It gives people a sense that they can predict many of the circumstances that affect them, but helps makes sense of the 'world' around the individual (whether that 'world' is the globe or their office environment), and also explains in some part where the individual sits and contributes in that world. It's the 'voice in the back of your head' that contextualises what one is doing, especially when that context may not be entirely clear.

Narrative can take on a life of its own – the 'rumour mill' is a leading example of a social process that can forge a collective, but negative narrative (such as 'we're slow, we've no idea where we're going, we are tanking'). Alternatively, narrative can be the story individuals tell themselves within an organisation describing that group's strengths, past victories, the confidence of future successes, and the like. Narratives can be contested by counter-narratives as well.

In the Solution ecosystem, a narrative can emerge about the performance of the Solution – which implies both the provider and the customer. 'Flying rates have boosted' or 'sortie rates are all over the place' can infer the quality and health of the overall Solution space. Narratives can also emerge regarding the provider ('they're highly responsive and reliable', or 'they cannot get their house in order'), as well as the customer ('they have no idea what we do and ask the craziest of things' or 'we have a good relationship based on mutual respect').

23.5.5 Influencing the narrative

Whilst narratives emerge, they can be influenced. This study is not a psychological piece; however, it proposes two key approaches:

- The pre-frame
- Managing expectations.

The pre-frame is about describing a preferred narrative up front – almost telling the story before anything happens, as a way of pre-empting the natural emergence of a story. It also sets a shared vision for a Solution ecosystem. It may include the headline metrics, but also some of the things the Solution provider promises to give, and the behaviours it promises to exhibit (see the above traits). Perhaps one example of a pre-frame is found in Boeing's efforts to develop the 777 in the 1990s. Boeing wanted to produce a different aircraft – a market-beating aircraft, developed in conjunction with eight key prospective customers. The B777's program leadership dubbed it 'Working Together [215],' creating a narrative that permeated the 10,000s of people involved with the program, signalling a significant change in the design philosophy and expected collaborative behaviours of staff.

Figure 73: The narrative cycle

The second approach is through appropriate strategies and interventions to manage customer expectations and experience. This is in itself is another research study of its own; however, it ranges from the appropriate release of information to the customer, patient explanations and education, breaking bad news in appropriate ways, as well as been able to understand other people's perspectives and priorities.

Of course, the challenge for a CIS situation is that these skills are best deployed throughout the various touchpoints that the Solution has with the customer, and not a handful of business-development folk. It becomes a Solution-wide imperative to be reading the customer's sense of satisfaction and understand it collectively as the provider.

23.5.6 Measuring narrative, managing success

Measuring *narrative* is a complex endeavour, requiring highly attuned political and empathetic skills. However, it's an essential capability for a CIS provider. True satisfaction is determined by *experiences*, not just achieved metrics. Thus, for a provider, success is not just found in managing the metrics – it's managing the narrative.

23.6 Core Thought 6: Solutions are organic, not mechanistic

It's tempting to use reductionist, mechanical thinking, and view a CIS as a set-and-forget 'sausage machine' that churns out the same result on a highly regular, programmatic basis. 'All that management need to do is oil and maintain the machine, and the delivery system will remain functioning over its likely long timespan'.

However, this study asserts something a little different:

- It is best not to think of Solutions in 'digital terms' – that is, on or off.
- It's more instructive to view Solutions in 'organic terms'
- Solutions exist in one of three states – nascent, transient, or steady

- As an organic system, it's 'a part of life' that Solutions will change, adapt and evolve with time. They're not permanently fixed.

23.6.1 A buzz of activity

Unlike process-based services which tend to have fixed, discrete delivery systems (e.g., component servicing on a lean repair line), a CIS is more fluid and prone to change in its structure and makeup as the environment around it changes. This environment may not change rapidly, but rather transition subtly much like climatic seasons. Of course, abrupt changes are also possible.

Consider the imperfect analogy of a natural beehive. It is a task-focused swarm that has forged its own habitat or localised ecosystem. However, as circumstances dictate, including changes to the seasons, the internal structure and arrangement of the hive morphs so to as adapt to this 'new reality', whilst maintaining its tempo of nectar collection with minimal disruption[32].

It's this beehive simile that affably explains the dynamic nature of Solutions – constantly morphing, rebuilding & changing in response to the environment that envelops it.

23.6.2 A dynamic steady-state

However, to perhaps use some conflicting terminology and mental imagery, Solution operations do exhibit some 'mechanistic' tendencies: ideally, they do achieve a stabilised, *steady-state*. This is not to mean the provider is static, fixed or has a consistent work profile – rather, it's in a 'dynamic equilibrium.'

To borrow the concept from aerodynamic theory, even with surges, pulses, reprioritisations, and other demands from a dynamic environment, the service provider is at a state of maturity where it delivers with high levels of consistency. The Solution provider – as discussed under the Service posture section – is a resilient organisation, with structures and capacity to deal with perturbations and quickly return to delivering consistent Solution operations.

However, the Solution/ecosystem's steady-state nature is threatened by a changing broader environment, unless it can adapt, reorganise and change. Achieving this continued steady-state in the midst of broader flux requires a greater sense of business strategy, intellectual rigor, and innovation to ensure the CIS remains relevant and competitive. This capability to adapt and change is a critical imperative for the Solution's leadership and management teams.

[32] This is perhaps scientifically imperfect; it's merely an analogy to demonstrate a point

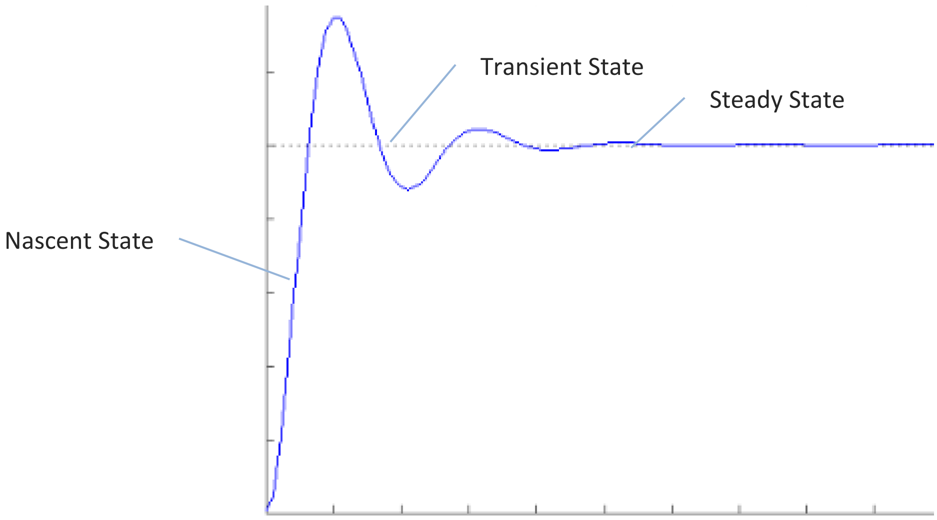

Figure 74: Solutions exist in various states

This does not mean, however, that the Solution is static or operates without encountering challenges. Indeed, there is still the presence of crises that need to be attended to – however, a steady-state operation is where there is a sense of routine and that most of the taskings, situations, and challenges it faces are prepared for. This is in juxtaposition with an operation that is in a 'transient state' – a concept that is echoed in the section on service posture, and further expanded in Chapter 24 on Solution lifecycles.

Table 9: The three key Solution states

	Nascent State	Transient State (activation segment)	Steady state operations
Nature	Embryonic & developmental. Procedures, structures, and new organisational rhythms are being designed, stood-up and prepared for.	Significant problems and wild fluctuations on an un-programmatic basis Particular emergence of significant or fundamental/systemic problems and queries that must be solved, or at least understood before been able to 'settle.' These are often 'one off' or 'first seen' issues.	A greater sense of routine and an ability to respond with reasonable clarity to challenges and crises that emerge Fluctuating volumes of more routine challenges, with the occasional 'crisis' or significant, surprising challenge to be overcome
Solution-Provider Organisational Characteristics	Schedule-driven (getting the Solution live by a specified launch date) Development-orientated (there are lots of facets and aspects to the Solution that must be stood-up)	Familiarity and confidence in the new arrangement/order still growing Problem-solving capacity is not quite as routine and is reduced by unfamiliarity and less clarity on the nature of the problem ('what do we do here?' versus 'here's the problem, let's fix it') Still building resilience and 'balance' for a steady-state	Familiarity and confidence in the new arrangement/order established Has an established and robust problem-solving routine Not impervious to significant shocks, but has sufficient organisational stamina, stability, and poise to understand, tackle and recover from such crises
Misconceptions	Linear progression (some challenges and impediments must be overcome in standing-up a Solution, including 'unknown unknowns' or considerations that hadn't been captured in the contract)	Unorganised and uncontrolled chaos Linear ramp-up process	Highly consistent and repeated programmatic activity A constant-speed output-machine 'Things going normally' A perfect match between provider expectations and customer demands (i.e., no surprises)

23.7 Core Thought 7: Solutions need strong delivery management systems tempered by an ongoing service strategy

Despite the dynamic and ever-changing nature of Solutions, they do need a highly defined Management System, including all the normal elements of a meticulous Quality Management System. This is particularly the case where aircraft configuration control is affected by what the Solution provider does (namely maintenance, engineering, and logistics).

Such work is defined by policies, processes, and procedures that cover the planning and execution of the detailed activities necessary to deliver the Solution, generally packaged up as a management system.

However, this study does issue a word of caution around rushing to 'copy-and-paste' implementations of management systems from other parts of the enterprise, into the Solution ecosystem. One observation this study makes is that there is the potential for a disconnect between the changing customer imperative and expectations, and the way in which key functional areas perform their tasks – there will most likely be a need to 'rebuild the beehive' with time, and this needs to be accounted for.

This study proposes that these meticulous management systems need to be subject to a management methodology that accounts for the unique characteristics of a Solution, expressed in a 'game plan' this study calls the Solution Management Framework, and captured, documented and articulated through the Solution Management System.

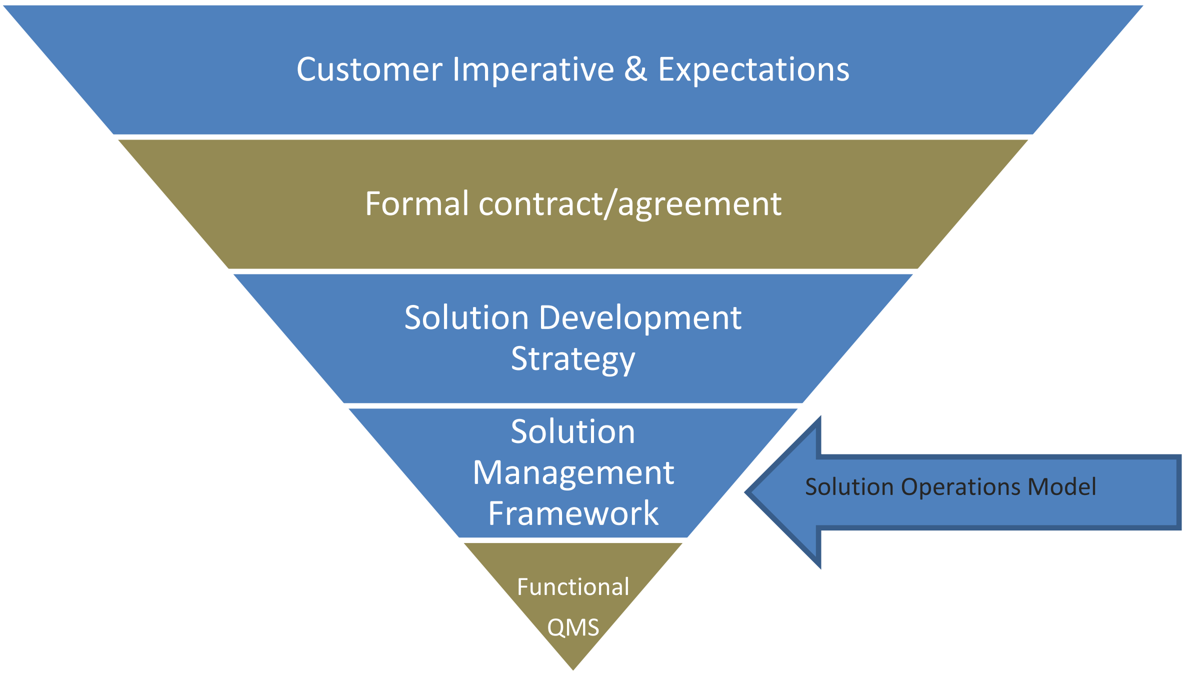

Figure 75: Solution management frameworks hierarchy

23.7.1 Solution Management Framework

The Solution Management Framework is the documented architecture of how the Solution will organise itself to deliver against the customer's expectations, as well as the broader company's management requirements. It is mindful that Solutions are not 'pushed through a hole-in-the-wall,' but rather are collaborations, and thus need to management and delivery framework to reflect this.

Key to this is the Solution Operations Model – the mapped and articulated *service delivery system* that the Solution provider emulates in getting aircraft and kit out on time; getting queries and requests answered; getting problems fixed speedily. When the customer has a flying program to meet, or other issues to solve, it shows how the provider mobilises and organises itself to meet it.

This Solution Management Framework is perhaps understood as the project management plan in place at a point in time for how the organisation is going to deliver. It acts as the high-level description of:

- The key functional business management systems and how the connect into this broader operation (e.g., Engineering Quality Management System, Maintenance Management System, etc.)
- How the Solution provider integrates the various activities of the Solution together under a common, goal-focused yet quality-conscious management framework. This involves significant amounts of coordination and planning to ensure what the customer is after is both understood, processed, and delivered-to-expectation (time, quality and specification) on an ongoing basis
- Articulates the structure and design of the Solution provider organisation
- The customer contact plan, including key forums, communications channels and collaboration/decision making protocols. This includes how compromises and workarounds can be facilitated with the customer – e.g., permitted carried forward unserviceabilities that won't affect mission success but will ensure fleet availability.
- Information sharing protocols – from safety reporting to financial reporting, to other process metrics
- Key delivery arenas – what are the main fronts the provider must provide a Solution on or through (e.g., scheduled configured fleet availability, technical publications/data, technical support, project management of capability enhancements)
- How customer demand 'signals' are captured and processed – whether by explicit request or collaboration (e.g., course requirements for role equipment), or perhaps more implicitly.

It is more than process mapping. A process is an end-to-end description of a task, whereas a system is a broader concept that explains interactions, implications, taskings, monitoring, and feedback, all aimed achieving some outcome. A process simply works towards an output – an output that a broader system uses to achieve an outcome.

23.7.2 Solution Development Strategy

Where the Solution Management System articulates the 'fixed' delivery system, the Solution Development Strategy might be considered to be the 'high level game plan' for the Solution provider to position itself for success now, and in the time to come.

It seeks to answer how the Solution provider will:

- Identify the complex nature of its customer – understanding the internal power structures, influencers, end-users, and those whose cooperation needs to be secured to ensure ongoing Solution success
- Identify its customer's 'tactical,' daily needs – both explicit and implicit – now, and into the future. In other words, what mechanisms will be used to identify demand triggers
- Ensure the Solution ecosystem will be a collaborative one where joint decision making is made (even with the customer ultimately having sway)

- Recognise, architect, and map the Service Delivery System, including key delivery lines, modes and fronts
- How will the Solution provider monitor and track changes in the customer's key imperatives over time
- Adopt a posture and expectation in itself to change, and re-architect the Solution with time as the customer imperative changes
- Seek to enhance and improve the Solution with time (in terms of quality, satisfaction and efficiency)
- Maintain and enhance its competitive stance to ensure the continuation of the Solution, as well as promote new business for the company.

As a high-level game-plan, the Solution Development Strategy acts as a business plan, but also as a service requirements blueprint. It lays out the parameters that the Solution Management System must adhere and adapt to but also outlays how the Solution provider's leadership team will manage the Solution in the long term. It also focuses the Solution provider to think in more complex terms just who the customer is (e.g., the customer power structure, including contract manager, end users, and those who have an influential voice within the customer enterprise).

23.8 Core Thought 8: Solutions require a long-term management posture

One framework that is proposed to be a cornerstone of a Service Development Strategy is the notion of managing the Solution on various time horizons. This requires a long-term management posture.

23.8.1 A management perspective

Stepping aside for the ecological analogies for a moment, it's important to recognise another facet of a Solution from the provider's perspective: it's a business.

Depending on the organisation, the provider's infrastructure and organisation that makes up its part of the Solution ecosystem tend to either be a somewhat autonomous business unit of its own, or part of a broader business unit focused on Solutions in some way.

Consider the first case study where it was part of a business unit focused on the broader Air Force/airborne military customer, with commonalities of governance structures, leadership team, and venues. Either way, these business unit structures will tend to be profit/loss centres and have their own leadership team.

As such, Solution leadership teams must be strategic in the way it goes about its business – that is, focused on 'what's next', and not just the day-to-day delivery, constantly evolving the Solution ecosystem to remain effective in the future. This requires an explicit management framework.

23.8.2 Looking along three horizons

To better understand this imperative for managing future state, this study turns to a mental framework developed by the McKinsey group called the "Three Horizon Approach to Innovation" which was published in the book *The Alchemy of Growth* [216].

The three horizons model was introduced in the context of studying firm profitability over time, and how that with time firms have a declining revenue and profit growth profile. The model shows how firms reinvigorate themselves over time to sustain growth over the very long term.

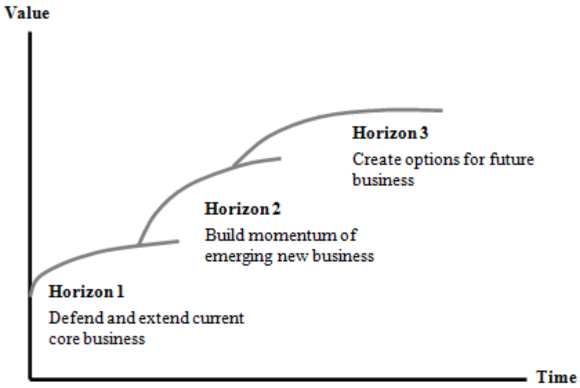

Figure 76: Three Horizon Approach to innovation [216]

The model's developers articulate that whilst no one can predict 'what's next,' by looking to the next three planning horizons, firm management can contribute to long-term success by managing the day-to-day business simultaneously with initiatives intended to reinvigorate itself over the medium and long terms.

This study takes this model beyond its original context and into the Solutions and services domain as a way of generating a more insightful understanding a management imperative in this domain.

23.8.3 Creating a long-term management posture

The three horizons model is likely a useful management posture that contributes to the long-term success of the Solution, particularly given their often enduring, long-term nature (especially if in engaged in a sustainment program of an aircraft type).

It is a management posture that drives the Solution provider to continually be mindful of factors that could affect the Solution's steady-state nature, as well as future opportunities for the Solution. It does this across all three horizons simultaneously, in two ways:

- **Environmental/external factors:** Mindful management of future changes, challenges, threats, and circumstances which may destabilise the Solution from its steady-state, whether they are negative events or positive ones such as taking advantage of new opportunities.
- **Internal factors/capability:** The potential internal threat that the Solution provider starts to lose focus and begin atrophying. Maintaining the Solution's ability to be beneficial to its customer (its 'value'), maintaining focus, and maintaining essential strengths and capabilities

(including knowledge) are essential for maintaining a steady-state Solution ecosystem in the long-term.

The original three-horizon model envisages strategic initiatives and activities to secure the long-term health of the business. However, this study would affirm that even if no actions or initiatives are raised and that this management posture is merely expressed an ongoing point of discussion, this may be sufficient to ward against such atrophy and loss of a competitive edge.

To support this endeavour, there are three time-based horizons on which the Solution needs to be managed:

- Horizon 1: Maintaining day-to-day capability
- Horizon 2: Evolving the Solution narrative
- Horizon 3: Goths at the gate.

Whilst these horizons roughly map to a timeframe, they also map to the ‘size and significance’ of a prospective issue or challenge. Some of these factors can start to be in train today, although their net effect might take some time to be realised fully.

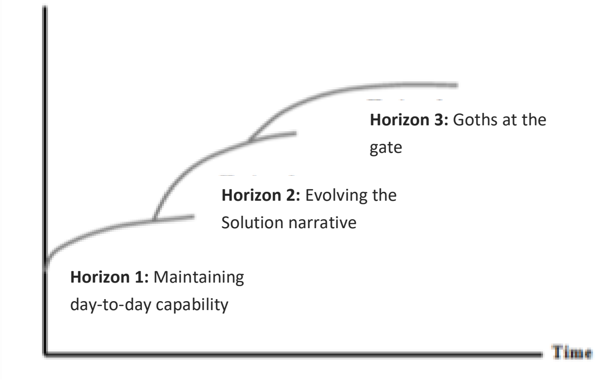

Figure 77: Three horizons management model

23.8.3.1 Horizon 1: Maintaining day-to-day capability

The first horizon is concerned with factors that have an immediate effect on the provider’s – and more broadly, the Solution ecosystem’s – ability to execute its daily business and to meet day-to-day goals in a steady-state fashion. It is primarily focused on the coming year’s daily operations. In other words, the ‘well-oiled delivery machine.'

This includes ensuring:

- Ongoing availability and supply of resources (including staffing, materiel, and data)
- Inherent ability to be flexible and have suitable capacity to adjust to pressing issues as they arise on a daily, weekly and monthly basis. This includes the provider’s ability to successful execute workarounds.
- Adherence to price/cost parameters.

23.8.3.2 Horizon 2: Evolving the Solution narrative

The second horizon is concerned factors over a 1 to 5-year timeframe, or be of sufficient magnitude that it consists of an evolution to the Solution.

These include:

- **Adjustments in expectations:** where the customer starts prioritising other facets of the Solution over others. For example, in case study 1, an important metric was suddenly reprioritised when the customer reduced its flying hour target of the training squadrons. This in turn had an effect on the Solution provider and make-up of the Solution.
- **Financials:** For example, a transient budget situation that might put a halt on a planned capability development or enhancement, or; continued pressure to make incremental improvements in cost performance.
- **Subtle evolutionary changes**: These include medium levels of technology insertion (additional weapons, or one-off avionic upgrades); realignments of reporting and decision making in the customer organisation, or; re-measurements of the contract (such as a modification to the way performance is measured, or an adjustment to the target figure)
- **Consequences of past performance:** Where Horizon 1 performance (and thus trust) is either rewarded, managed, or punitively responded to. These consequences can have an impact on the Solution provider's ability to deliver a steady-state Solution.
- **Opportunities for improvement:** Also opportunities to improve day-to-day business.

23.8.3.3 Horizon 3: Goths at the gate

This third horizon deals with factors anywhere between about 5-15 years out but also deals with quite revolutionary 'threats' to a steady-state Solution – the 'several-hundred-pound gorilla' lingering in the distance that could cause some major destabilisation and damage. Some of these threats include:

- **Provider organisational atrophy:** including loss of critical knowledgeable/skilful staff or a loss of enterprise-wide attention to service operations, leaving the CIS to 'wither'
- **Major scope changes**: including a significant change to the Solution's concept of operations, or a step-change in responsibilities (such as increased scope or activities, or a reduction)
- **Major changes to the pricing or contract type**: generally following long-term pricing pressures and imperative to reduce costs
- **Ageing aircraft challenges:** When a Solution is new and is using new aircraft, Solution business is reasonable steady-state, perhaps except for some initial bathtub curve effects. However, as aircraft exhibit ageing characteristics, they can severely impact the Solutions provider's ability to perform to the known cost profile. Spares can become sparse, OEM support can become thin, subsystem reliability can decrease, cracking/fatigue can increase repair costs, turnaround times can blow-out, and aircraft availability be reduced. The EEF also needs to spend more time on monitoring the state of the fleet to ensure equivalent levels of safety are maintained, either meaning a reduction in capacity for other tasks or there been a need to increase pricing to reflect this added workload.
- **Strategic changes to the customer imperative:** where substantial changes happen the broader environment that could impact the Solution business. In a military context, this might mean an outbreak of new tensions or specific threats (e.g., emerging technology that puts the customer at a tactical disadvantage), and thus the customer needs to respond in ways to counter that

scenario. This was seen in the proposed mid-life upgrade for the Milvus fleet. In the civil context, new market opportunities might require larger fleets, or new aircraft types to be added into the Solution environment. Or conversely, a significant downturn might lead to grounding a portion of the fleet.

23.8.4 One final horizon

There is, however, another element to the third horizon: the notion of developing the next-generation iteration. This is working towards elevating the Solution to a place where it totally transforms as a 'next generation' concept of that Solution is considered and established.

In the aviation context, this may mean a new aircraft, a new operating concept, and new metrics. However, once the Solution provider has been able to embed itself with its customer, ideally, it should strive to remain a provider for the life of that customer.

23.9 Core Thought 9: Solutions require an active posture

It's easy to overlook among this discussion of traits what the term *Solutions* implies: someone *solving* a problem or need. A verb, not just a noun.

Exerting a positive influence on the customer organisation and *helping* them be successful in their imperative requires the Solution service provider adopt an active, dynamic, front-footed posture. This almost goes without saying – however, as previous research on manufacturers in the services space reveals, providers can quite easily have insufficient energy, focus, and preparation to succeed in this space.

This study proposes that a service provider's posture can be mapped using two aspects:

- **Stance:** The way the provider is structured, managed and prepared for the activities it's engaged in as part of the Solution
- **Disposition:** The level of energy to drive customer business outcomes.

These two aspects are instructive, but not exclusive – there are likely many other ways to plot service posture.

23.9.1 Stance

In a Complex Integrated Solution, there will always be a level of 'fire-fighting' – unexpected and unplanned matters that arise that must be overcome and managed to achieve the goals of the Solution. This is significantly a matter of structure, planning, and preparation – as Weick describes it,

> "[The] ability to deal with a crisis situation is largely dependent on the structures that have been developed before the crisis arrives [54]."

It is this resilience that forms a key capability of a Solution provider, and an important facet of the posture of the provider. This study highlights three discernible 'levels' of this stance:

- **Reactive:** This does not imply idle, 'lazy' or unwilling. Rather, it's a weaker stance whereby the provider is constantly behind 'the game,' has little capacity to absorb crises and surges, does not have sufficient resilience to quickly reorganise and rebound following a crisis, and finds it difficult to control priorities. It reacts – rather than responds – to the issues at hand, and its priorities are often set at the beleaguered insistence of customers or other circumstances, rather than through self-management. It is unable to scan the environment for any likely upcoming scenarios that may impact on the Solutions goals. Its stance is to survive, and its instinct is to keep its head 'above water.'
- **Responsive:** A responsive stance is stronger than a reactive one. The provider has a greater capacity to respond to and absorb crises, and it has an ability to deal with the issues and prioritise. However, it is still not fully on the front-foot – it still lacks a certain capacity or initiative to scan the environment for possible issues it's not prepared for (although it does do this). Its stance is to be ready for more-of-the-same/business-as-usual in a timely manner, and its instinct is to meet requirements but without going 'above and beyond.'
- **Proactive:** This is not to mean perfectly predictive, as not everything in a service environment can be certain or planned. However, a proactive stance is one where there is an element of preparation for likely scenarios, plus a capacity and resilience to deal with crises and surges. It takes the initiative to both ready itself for these known scenarios, but also to monitor and scan the service environment for other scenarios that it is not prepared for or could improve on. It actively works with its customer to understand issues that might affect the Solution ahead of time. It has a stance of reaching out and actively preparing itself, whilst its instinct is to demonstrate itself as a trusted partner ready to meet its customer's challenges.

23.9.2 Disposition

Disposition is concerned with the level of commitment and effort on the part of the provider to help the customer in being successful. It might crudely be called 'collective attitude' and is more a cultural/leadership trait, rather than an organised capability. This study identifies three broad categories of this spectrum:

- **Rigid & Orthodox:** a preference to default to more traditional ways of doing things and to what the provider traditionally knows, rather than actively adjusting to the customer imperative
- **Accommodating & Agnostic:** This kind of service provider is somewhat passive in that it will do as it's instructed, but will not necessarily 'rise to the occasion' with great initiative. It will be responsive – in the sense of being *cooperative* – but the energy required to focus the service provider towards enhancing the customer's condition and situation is lacking internally.
- **Progressive & Dynamic:** A progressive service provider is one that has high levels of organisational focus, initiative, and impetus to plan and execute its activities in a way that is highly advantageous to the customer. It will go 'above and beyond' the minimum, required effort, and will actively seek out ways to enhance the customer's condition and situation. It's a dynamic player.

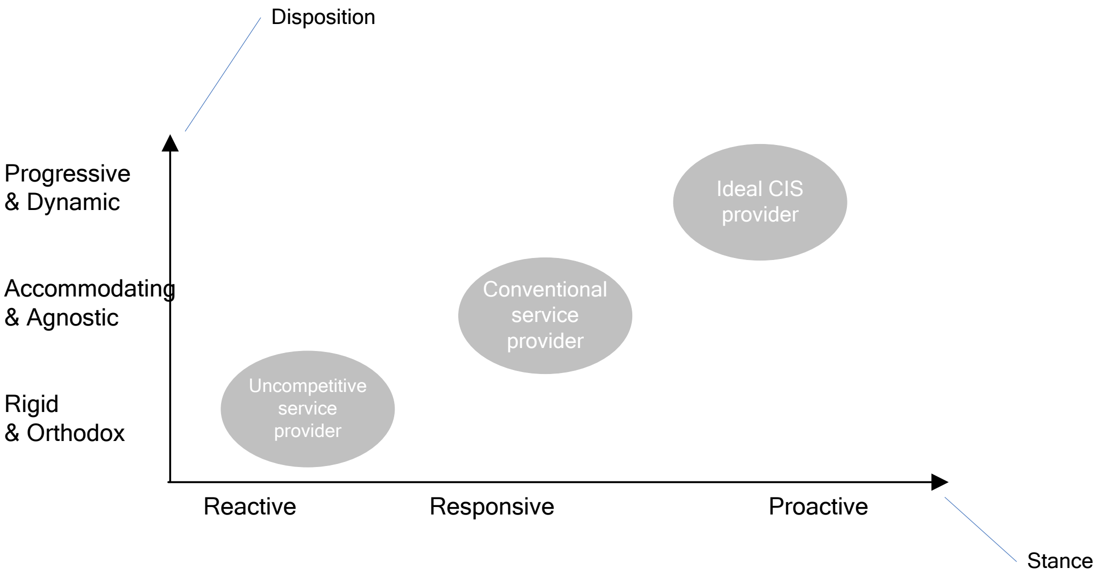

Figure 78: Service posture, as represented by the spectrums of disposition and stance

It should be apparent that a Complex Integrated Solutions provider's posture is ideally expressed as being *progressive/dynamic* and *proactive*.

23.9.3 Other elements of service posture in Complex Integrated Solutions

Exploring the concept of *service posture* is one open for further debate and research, and is highly connected to the notion of service strategy. However, this study asserts some interim observations that such a service posture includes the following elements:

- **Is an integrator on behalf of the customer:** A CIS involves many inter-relating elements of varying levels of sophistication. The CIS provider's role is to bring these various elements together, not just from a technology perspective, but from a service perspective as well. An aircraft will have subsystems and components from many vendors and suppliers from across the globe, but rather than the customer having to spend limited attention span on resolving cross-provider issues, instead they see one outfit that takes responsibility for bringing everything together in a joined-up and unified fashion. The CIS provider is the customer's advocate.
- **Single points of responsibility:** In a similar vein, whilst the Solution is delivered over several fronts and modes, there exists a single point of management responsibility (designated CIS provider leadership) and clear 'go-to' points for more detailed matters. Assuming a true partnership approach (and not a supplier mentality), the CIS provider is easy to do business with because routine matters are dealt with by people within the Solution empowered to deliver an outcome in that respect domain. When performance becomes questionable, there is

one leadership structure to be engaged with – not fragmented divisions across an enterprise, or across several enterprises.

- **Adaptive and adoptive of the customer's way of doing business:** Not merely recognising and hesitantly conforming, but willingly organising the provider's service management strategy and organisation around key ways the customer operates. Whether it be customer venues, operational pace, expected turn-around (contracted, or otherwise), or other concept-of-operations, the Solution provider actively seeks out ways of 'plugging in.'
- **Is 'hardwired' to take the initiative:** The Solution provider is astutely mindful that the Solution is something that is experienced by the customer organisation and its people, and does not just provide inputs. As such, the provider has a strong emphasis on the traditional, experiential 'customer service' angle of service management. Its conduct and demeanour are on the front foot, anticipating customer needs and taking the initiative – everything from simply providing a follow-up call on a matter its known the customer is keen to stay aware of, through to proactively scouring for new technologies that could be inserted into the Solution space to improve customer effectiveness.

In short, a successful Complex Integrated Solutions provider is one that takes responsibility and actively drives the complex relationship with the customer and its people.

23.10 Core Thought 10: Solutions demand a renewed logic

There's a subtle undertone that draws these previous nine core thoughts together – that seeking to execute a Complex Integrated Solution with a product-centric worldview induces too many 'blind-spots' to properly understand the nature of the Solutions space. Instead, a service-centric view provides a much more cogent thinking pattern.

An aerospace and defence firm can readily offer a Complex Integrated Solution such as product-service system or Complex Engineering Service System, yet may offer it from a product-centric perspective. In other words, a CIS is a type of business activity, not a system of logic – however, to best manage such an offering requires a more sophisticated understanding of the services space.

As such, what's the difference between the two schools of thought – product, and service – that might apply to a Solutions context?

23.10.1 A different manner of business

An answer to this question can be found in Table 10. It contrasts a service and product school-of-thought on 20 different parameters, ranging from organisational structure to customer orientation, to developmental process logic.

In short, a product-centric view of Solutions will try and apply deterministic, 'robotic' techniques to devise and operate a complex service program. It's an approach that works well in highly-controlled environments to quieten the complexity surrounding development efforts for sophisticated systems. However, Solutions involve people who are not always predictable and are motivated by a wide variety of factors that cannot always be controlled or even understood. Thus, a service-centric view is required to help marry the complexity of the systems involved in a Solution, with the complexity of the customer and provider organisational aspects.

Table 10: Contrasting product and service schools-of-thought in a Solutions context

Paradigm / Dimension	*Historical / Traditional Logic*	*Emerging / Establishing Logic*
Dominant logic type	Product	Service
Focus	Assets and systems	Capability and effects
Customer Relationship	Transactional	Relational
Need Characterisation	Meeting performance needs through solving technical problems	Meeting business/organisational needs through a mix of assets/systems, services, information and intelligent, directed activity
Workforce capability profile	Technical disciplines key	Multi-disciplinary approach across technical, operational and logistical fields
Organisational approach	Organisation designed and structured around the product	Organisation designed and structured around the customer, and more-so, their mission or imperatives
Nature	Mechanistic (focused on making automated processes)	Organic (focused on people working towards a smart, common interest)
All eyes on	System	Customer mission/imperative
Structure	Functional	Customer's core business elements (e.g., structured along benefit delivery lines, rather than discipline lines)
Offering posture	Customer adapting to offering	Offering adapted to customer
Perspectives on 'intangibles'	See intangibles as secondary	Sees intangibles as part of core business
Customer orientation	Customer needs-focused	Customer intermeshing
Customer engagement	Interface with customer (touchpoints)	Integration with customer (linkages)
End goal	Construction/deployment/delivery	Sustained, enhanced state
Delivery System Properties	Fixed/mechanical/'set & forget'	Metamorphosistic/evolutionary
Posture towards customer	Handing over: benefit realisation in the hands of customer ('Here you are')	Working together: benefit realisation a live collaboration ('How is this')
Development Process Logic	Isolate system development from the user/customer with controlled inputs (e.g., requirements documents)	Collaborate with the customer in the development of the service solution
Development Environment	Systems developed and delivered in an environment of certainty	Solution designed and developed in a dynamic environment of uncertainty
Operational Environment	The environment is defined by constraints and requirements (the operational environment is divorced from the design and development environment – taken 'offline' to develop the solution)	The Solution provider is immersed in the operational environment, and its workings are 'exposed' and on display to the customer
Concept of Resilience	An emphasis on product/hardware reliability and resilience	Need to build solution resilience and service reliability/consistency consciously. It's an organisational trait, not a product characteristic

23.11 So, what's a Complex Integrated Solution?

The following chapter on finding a Solution lifecycle extends the ideas and logic presented in this Chapter, and so is not the final word this study has to offer on the matter. However, it's an important juncture to actually ask this question: what does this study actually say Complex Integrated Solutions are?

It's a definition that perhaps echoes the definitions of *Integrated Solutions* as found in Chapter 9. However, this study views *Complex Integrated Solutions* as:

> A business activity typology to identify, source, develop, integrate, implement, energise, deliver, enhance, refine, optimise, sustain and support all the elements required to meet a customer's imperative, established as a coherent ecosystem with the customer, and provided in an economically viable way.

23.11.1 A management methodology?

Whilst this definition might be neat (or convoluted), does it help bring together all the elements discussed in this chapter? And more importantly, does this chapter's contributions offer up a viable management methodology?

This chapter presents several key ideas that can be used in constructing a system-of-logic for solutions – a contextualised worldview that helps professionals orient themselves towards the true nature of the activity they're seeking to influence and manage. This includes key ideas as:

- Solutions are ecosystems built around a customer imperative and that enhance a customer's condition or circumstance
- Solutions exhibit more 'organic' qualities than 'mechanical' ones
- Solution operations are ideally represented as converging on a 'steady-state', but also existing in other states (namely transient, or nascent if embryonic in nature) in certain circumstances
- Solutions require an 'active posture' by the provider.

These are in stark contrast to more traditional product-centric concepts such as conformance to specifications and schedule, fixed-requirements, and lifecycle phases. They're not a complete management methodology – however, they do present compelling ideas that can be applied to a Solutions environment to better understand and manage them. As such, these are unique ideas to help practitioners understand Solutions from a service-centric viewpoint.

However, there's one more insight that's worth considering that may help displace one of the most powerful of product-centric thought patterns: the notion of the product lifecycle.

CHAPTER 24

Towards a New Lifecycle Concept for Complex Integrated Solutions

24.0 The circle of life

This chapter continues a core thought developed in the previous chapter that Solutions are 'organic' rather than mechanistic concepts – that is, they take on properties that are synonymous with life rather than machines.

This thought is coupled with a perspective on one of the most well-known concepts from systems engineering that has so coloured the aerospace and defence context: the systems lifecycle. It's a powerful model that provides great clarity and perspective in devising, implementing, managing and using a complex system. However, could it be a little too powerful an idea?

24.0.1 Too powerful an idea?

This study makes the assertion that whilst it's highly useful, it can distort clear thinking about building something that is not mechanistic in nature, such as a Solution. It's also a concept that can highly influence the management methodology of sustainment Solutions, as evidenced by:

- It's a concept replicated in many procurement policies [28, 39, 40, 217] and procedures of various DoD agencies (i.e., the acquisition and sustainment efforts of various DoD's are built around a system, rather than around raising and operating organisational capabilities)
- In the first case study, DefTech Global managed its business based on the systems engineering lifecycle, basing its contract management reviews, governance structures and key management procedures off it.

The lifecycle approach is a robust framework for managing the complexity of system development programs, but it has less applicability to other business activity typologies, such as consulting services, or complex service programs. It doesn't account for the true nature of these typologies, and thus an adequate management approach is overlooked.

Hence, this chapter seeks to present an alternate idea of understanding the lifecycle of Solutions – not to replace the systems engineering lifecycle, but to accompany it. It's been inspired by some of the ideas presented in Chapter 9, but highly informed by the observation across both case studies of the organic nature of Solutions, and the fact that their existence is found in various states.

24.1 It's about seeking a steady-state

24.1.1 Foundational ideas

In presenting this study's concept for a CIS lifecycle, there are some important basis' that must be understood.

Firstly, the concept presented in this case-study could apply to any operation or organisation; in some respects, it's a start-up model rather than a system development model. However, it's developed with a Solutions paradigm in mind and is presented for that purpose.

Second, it's based on an important piece of logic – that Solutions are found in three states:

- **Nascent:** the embryonic stages of formation and development
- **Transient:** major perturbations to regular operations
- **Steady:** a greater sense of routine (this doesn't mean a lack of challenges, but an inherent capacity to recover from 'shocks' or operational unrest).

Third, Solutions follow a 'segment-cycle' towards a Steady-State Solution, rather than a lifecycle. However, even this is not an accurate description. This 'lifecycle' model is less of the linear stages through life, and more akin to the various electron energy levels of the atomic model. In fact, this study uses the term *segment* rather than *phase* to describe this idea for three reasons:

- These segment efforts have the potential to be concurrent, rather than purely sequential in nature (although these segments are most likely to played out in a sequential manner)
- Phases infers discreet (albeit sequential) chunks of activity and only connected in the passing of tie, rather than been highly connected in the present
- Lifecycle phases can sometimes invoke the wrong meaning – for instance, the notion of 'disposal'. Ideally, there's no Solution 'death' or disposal (except if provider or customer folds). Rather, the Solution may evolve towards a transient (or in extreme instances, nascent) state again and again to be 'generationally renewed' rather than replaced (even though the central technology piece might be changed out).

Fourth, there are various modes of establishing a new Solution. Some Solutions may be taking over existing functions that a customer (or another party) may have been performing; some Solutions involve standing up entirely new operations (including a new fleet of aircraft). As such, the levels of complexity and effort for each segment will differ for different establishment modes. However, these proposed segments are still likely to be useful in understanding the Solution realisation endeavour.

24.1.2 The key segments

This study proposes that a steady-state Complex Integrated Solution is arrived at in five segments:

- Strategic Engagement

- Solution Architecting
- Solution Design & Development
- Solution Integration and Implementation
- Solution Activation
- An ‘arrival’ at a steady-state Solution.

Figure 79: Solution segment-cycle

However, it’s important to recognise that once the Solution has ‘arrived’, it's not a permanent fixture without continual effort and insight to remain in a steady-state (one that maintains an active service posture as described in the previous chapter). Also of note is that this chapter assumes a sustainment or fleet management-focused CIS is the focus of this concept, although it could be adapted to other contexts.

24.2 Strategic engagement

Engaging with the customer organisation on an ongoing basis is an essential first segment for the development of a lasting Complex Integrated Solution, particularly where capital-intensive systems and concepts are involved.

The pure acquisition of such systems can take years, and in some instances, over a decade [218][33]. Engaging with the customer organisation at the embryonic stages of recognising a need is important so that the prospect provider can influence the process towards a beneficial outcome for both parties.

In this segment, however, it's just as essential that the manufacturer listens to the customer organisation, ask probing questions and seek to gather further insights about both the communicated need and the actual/tacit need. Understanding the customer's imperatives, be they economic, operational or political/social, is essential in this engagement segment. A firm grip on the context the Solution might be established in helps with the formulation of a compelling bid, and the mobilisation of a successful Solution, should the firm win a contract to service the customer.

It was this kind of strategic engagement activity helped give DefTech an insightful advantage for the Milvus Solution. When providing the prospective customer with a tour of its manufacturing facilities, key NAAF representatives began to unofficially 'push' the firm to consider a new cockpit layout and configuration utilising newer technology. The customer's desire was to have a trainer aircraft 'mimic' the cockpit and displays of the NAAF's front-line fighter for training and continuity purposes. This type of insight gave the firm an insight into how to win the contest against other competitors, and not just respond to a formal request for proposal.

Engaging early with the customer also helps influence and refine an accurate and explicit set of expectations (itself resulting in a formal request for proposal). By helping the customer in the process of working out the key concept of how a Solution might be best construed (i.e., the high-level architecture), it can mean the firm can mobilise a Solution that can meet a realistic set of expectations and not one where the customer has made inaccurate assumptions that cannot be sustainably serviced.

In addition, by engaging with the customer early, the firm can be a source of original ideas and perspective for the customer's thinking process as it converges on a request for proposal. In the first case study, this saw DefTech making the case for a staggered approach to the development of the Milvus, with a major mid-life upgrade as part of the lifecycle management of the aircraft. This concept became embedded in the RFP and became a 'budgeted expectation' (i.e., it became a fairly immovable policy of the customer). In effect, this presented the winning firm with an additional source of business in the order of $300million.

Naturally, it's these types of strategic engagement activities that lead to the strategic architecting of the Solution – the next key segment in developing a Solution.

[33] The Royal Australian Navy started planning its next generation of submarines up to 15 years prior to planned service date

24.3 Solution architecting

Researching, defining and communicating a clear, compelling value proposition for the customer organisation is the key focus of the Solution Architecting segment.

Following the customer's issuing of the requirements for an Integrated Solution (including the major areas of service delivery, the performance metrics & expectations, and contract mechanisms), the prospective provider must work up a compelling case to be selected. This includes examining the needs and priorities of the customer to identify and enunciate unique strategies and features that will hopefully sway the decision of the customer favourably.

In the first case study, DefTech had a clear view about what materiel aspect of the solution would be, at least regarding the platform to be proposed. However, the company considered alterations to the existing platform, incorporating customer feedback about the cockpit systems, as well as outlaying an upgrade program proposal for embodying new sensor suites at programmatic points in the aircraft's life. In addition, the company also focused on other non-aircraft dimensions of the Solution, including in the offer the assembly of the majority of the aircraft in-operator-country (a significant political points-winner), and the construction of a support facility adjacent to the NAAF Squadrons. In short, the firm had identified a Solution that addressed the complex array of needs and imperatives that the customer as a whole had.

It's in this architecting segment that a range of ideas and options are examined to determine the most optimal way of meeting the Solution requirement. As a result, key aspects and facets of the proposed Solution (which may be 'locked in' as a real Solution to be deployed) are defined. To achieve this, the provider must engage in seversl activities, including:

- **Defining a Solution Concept of Operations:** not just how the customer will use the outputs of the Solution (in this context, mostly aircraft), but the concept of how the Solution itself will work (e.g., broad breakdown of responsibilities, and a high-level Solution Operations Model)
- **Modelling:** A critical imperative for the firm is to ensure that whatever is offered to the customer can, in fact, be delivered and managed as per the price stated in the offer. This involves significant amounts of modelling of the financials, scenarios, and activities that stem from a proposed Concept of Operations
- **Strategy Development:** This modelling also supports and informs the development of the Solution Development Strategy – namely, the set of long-term choices that could either make the Solution successful or be a commercial failure. This includes defining the business model, and creating a business plan, showing how the Solution will make money for the provider, whilst also identifying a price-service point that will likely represent value for money for the customer.

It's in the Solution Architecting segment that the provider firm stands-up a business development team to respond to the request – however, this study would also assert that it's at this point that the first embryonic stages of a new Solution ecosystem are realised. As such, this is not merely a bid team, trying to sell an idea or offer – rather, it is potentially the first stages of a new business unit.

Hence, this is gamut of activity is not merely described as being a 'bidding phase', but rather one that lays the groundwork for the whole scheme, should it be selected. It ultimately is the architecting of the Solution.

24.4 Creating the Solution, transforming the customer

The two segments of *Solution Design & Development* and *Solution Integration & Implementation* are discussed together, as they are highly connected, perhaps more than the other segments.

In addition, apart from the design, development, delivery and integration of all the elements required for the Solution, this two segments is highly focused on something else: customer preparation and readiness.

Embedded in these segments are not merely a 'ramp up' for the provider; it also has the potential to be a significant change exercise for the customer organisation. The provider and customer need to work together to assist in this change process. This covers everything from process and procedures, to data and support infrastructure, through to managing and supporting the substantial 'being human' element that change tends to invoke. Whilst this study is not focused on change management, it's important to recognise that with the onboarding of a new Complex Integrated Solution, there exists the potential for a sense of disruption, uncertainty, and even loss. These are factors both the customer organisation and the new Solution provider need to mindfully manage, particularly to win the support, trust and cooperation of personnel – essential for any sense of collaboration or co-production of value.

24.4.1 Solution design & development

The Solution Design & Development segment involves the detailed scoping, planning, designing, developing, initial testing and preparation of the key elements of the Solution.

A significant amount of the following elements require detailed customer engagement, as it ultimately constitutes the building blocks of the Solution ecosystem. These elements include:

- **Rollout plan:** Jointly creating a plan to roll-out the Solution, stand it up and activate it
- **Detailed service scope:** Scoping and identifying the specific handover and transition of responsibilities and activities
- **Building Relationships:** Establishing relationships with operational and management personnel of the customer organisation (up until now, most interactions will likely have taken place at more senior levels). This includes planning and launching relationship and trust building initiatives and events, and to facilitate the cultural and relational aspects of change management.
- **Organisational Design:** This is not merely the organisational structure, but a more holistic arrangement of the capabilities, activities, resources, reporting lines and leadership structures that ensures the organisation has sufficient resilience, capacity and drive to achieve the Solution's goals. Given the aviation context, there are certifications and organisational approvals that must be obtained, and this feeds into this organisational design process. It's also highly connected to the Service Operations Model and the Solution Management Framework.
- **Service Operations Model:** In particular, the agreed way in which the Solution will operate, including how and what service demands are made, and how the customer can expect the Solution provider to respond.

- **Solution Management Framework:** The agreed (and where required, certified) set of processes and governance structures to ensure the integrity of the several aspects of the Solution (including aircraft/safety, financial and security).
- **Infrastructure planning:** What major changes or new facilities, foundational IT platforms, databases or networks need to be implemented?

In addition, there are some slightly more 'in-house' elements (following the customer's issue of a formal requirement). These include:

- **Design & Development of key platforms and systems:** This primarily includes aircraft or a new sub-model of an aircraft adapted to meet the customer's specific circumstances. It also includes other major systems, such as simulators, training aids, mission planning algorithms, or system health algorithms attuned to the customer's needs. It is here the traditional systems engineering process and logic is the ideal framework for realising a rigorous design. Within this segment of activity, one would find the first flight of the first aircraft.
- **Initial compositional work in devising the Service Development Strategy:** Taking the efforts of the Solution architecting team, and using it as the groundwork for key discussions about how the Solution is to be operated and developed with time.
- **Organisational Stand-Up:** The Service Delivery Group/business unit that will ultimately deliver the Solution is in the process of being established, including the selection and initial training/development of key leadership and management personnel.

It is perhaps unusual to reduce the highly intensive and expensive activity of aircraft development as a mere line item in the Solution development process. However, the emphasis in the customer/Solution space is about the effects those assets can yield, not so much on the intellectual impressiveness of the system development activity, as remarkable as it is.

24.4.2 Solution integration & implementation

The Solution Integration and Implementation segment is where the key elements of the Solution are introduced, brought together, tested and validated. It's this segment where the 'physical evidence' of the Solution begins to significantly emerge.

It's also where the bulk of the organisational preparations for both the customer and the provider are in full-swing. While this study designates this segment as Integration and Implementation of a Solution, there is a particular emphasis of this segment that, in itself, constitutes a complete solution to a significant need. Namely, preparing the customer organisation for a new concept of operations and, in the Solution mode assumed of this study, a whole new aircraft type.

In short, it is a new era for the customer.

Before been able to accept and operate a new aircraft type, the customer organisation must be prepared and equipped with the necessary knowledge, training, information and some level of experience to employ the aircraft safely, effectively, and reliably from day one. This development process takes time and is an activity that the CIS provider needs to be ready to provide for.

A lot of these support activities can be provided by standing up within the Solution development team the fore-runner to the EEF – an outfit tasked with assisting the customer in the step change associated with a new aircraft and its capabilities, and more importantly, taking advantage of it. In addition, this

EEF unit can assist the customer organisation in building its own learning and knowledge ecosystem and enhance its initial capability as an operator of the type (and subsequently into the future).

Some of these activities include:

- **Formal training program:** First cadres of customer personnel including 'train-the-trainers' of pilots and maintenance crews. The customer and provider need to work together to create an optimal training and development schedule.
- **Provision of 'live' aircraft datasets:** This includes training simulator data packages, mission and performance simulation data and algorithms, flight test performance information (particularly for bespoke or modified designs), and initial technical publications for the customer flying component to prepare them for how they are going to best deploy and use the aircraft.
- **Technical publications provision and development:** In addition to the provision of initial datasets is the collaboration between the Solution provider and the customer in developing procedures that are consistent with the customer's operating ethos, as well as to adapt into the customer's documentation system. This also requires technical support to the customer in the development of their own unique aircraft operating procedures.
- **Contextual immersion:** Embedding first-users and other key customer personnel with the aircraft development environment. This allows them to understand with greater richness the 'why' the aircraft designed the way it is, to appreciate the 'back house' technical support structure, and to develop relationships with the major system OEM.

In addition, in readiness of the Solution's 'go-live', the Solution provider also needs to ensure its own readiness. This may include:

- **Organisational stand-up:** Growing the core start-up team into a fully-fledged Group via recruitment and training/induction of operational staff (including maintainers, professional engineers, logisticians and planning staff
- **Service rehearsals:** Validating the service concepts and processes, as well as verifying connectivity and integration of IT systems and communications channels and forums
- **Certifications:** The various activities, functions and units that make up the Solution provider organisation need to apply for certification, and demonstrate compliance and readiness for that certification
- **Prime supply and support lines:** Begin to stand up supplier relationships, including spare-parts providers, major sub-system suppliers. Pools of spares and equipment need to be procured and delivered. Where major partners will be used, such as contracted maintenance service providers, these relationships and approvals need to be formulated, enacted and readied.
- **Infrastructure development:** The planned infrastructure development needs to be enacted and completed. This includes support facilities, office space, workshops, as well as computer networks and secure data back-up facilities

It's also in this segment that the aircraft at the core of the Solution receive certification and enter into full-rate production and acceptance testing.

24.5 Solution activation

The Activation segment is where all the initial elements of the Solution are not just ‘bundled together’, or even integrated. Rather, It’s where the rubber hits the road and where the Solution ‘goes live’.

Solution activation is where the intended potential of the Solution, with the associated expectations of customer and Solution-provider alike, starts to become realised. Whilst this segment sees several significant moments and events, it would be inaccurate to describe *Solution Activation* as one event – rather, it’s a whole segment of activity unto its own.

The key goal of the activation segment is developing and advancing a Solution ecosystem to the point where it assumes a ‘business as usual’ demeanour: that is, where it can be realised as a *steady-state* operation.

However, this study places a particular emphasis on an aspect of the Activation segment that is a little harder to quantify and project-manage. The major activity of inducing a new fleet of aircraft, route/mission proving them, and placing them into service in increasingly sophisticated ways is only realistic when the organisations that operate and enable them are expeditiously and intentionally developed to be proficient operators – both of the aircraft, but also of the Solution. This can be a process that takes several years.

24.5.1 Proficient

It’s important to qualify what is meant by ‘organisational proficiency’ in this context because the organisations involved are likely already capable and established outfits.

First, what it’s not intended to mean:

- A restriction to individuals (via licensing structures) – rather, this is an organisational trait
- Attainment of a qualification, such as the successful completion of a curriculum-based training course
- Perfection, expert or world-beating capability – it’s what is sufficient, whilst there been room for growth and development

Instead, this study views ‘organisational proficiency’ as:

- An outfit that has gained a specific, intellectual foothold whereby the organisation has mastered the ‘regular nuances’ of a new aircraft and way of operating. It’s moved from being a novice, to proficient, with scope to still yet become expert.
- An organisational trait that exhibits confidence, which leads to speed-to-act. Much of this entry-into-service activity is about building confidence with the new aircraft, and the new support arrangements.
- An organisation that has gained sufficient experience which means problems can be solved quicker, tasks performed faster, troubleshooting done more accurately.

In this aerospace context, there will always be scope for further learning, improving, adapting and changing. However, this concept of ‘organisational proficiency’ is where the outfit exhibits sufficiently ‘good enough’ organisational routines, experience, knowledge, and safety awareness to operate safely and effectively. In most instances, it's the adaptation of existing proficiency directed towards a mastering a new aircraft Type.

24.5.2 Towards a steady-state

The activation segment is where the Solution is in a 'transient state' – where significant perturbations are experienced, and significant challenges are overcome, but where there is a trending towards that steady-state nature. This emphasis on proficiency development isn't just an activity limited to either the customer or Solution provider – rather, it's a condition of the entire Solution ecosystem. That been said, each key partner in the Solution will have their own set of challenges to deal with in this segment, but must also collaborate together to advance the Solution ecosystem towards a steady-state.

On the journey to a steady-state operation, the Activation of the Solution does require careful management and close attention to the following attributes along the way:

- **Minimal interruption to customer's daily business:** Whether it be a regular scheduled flying program or continued throughput of students through a training program, the customer's core business and imperative cannot be materially affected during, what is for them, a transition
- **A safe introduction:** Particularly when still raising organisational proficiency levels, both the operator and Solution provider need to be mindful of ensuring a gradual approach to sophisticated operations to ensure an acceptable level of safety
- **Improving customer condition:** As already illustrated, the Activation segment is not just the delivery of a fleet and commencement of contracted services. There must be a deliberate approach to raising ecosystem proficiency – as such, this Activation segment is as much about fostering an environment of learning and improvement, as it is delivery logistics.

24.5.3 Support to the customer

Even for a competent flying organisation, the changeover to a new aircraft type presents challenges. Bringing in a new aircraft involves several proving stages – to both prove the aircraft does what's claimed, as well as prove that the organisation operating the aircraft can do so proficiently. There is also the prospect of a rethink of tactics, ways of using the aircraft, and other operational procedures. Detailed aspects, such as a change in navigation procedures[34] due to new technology available in the new aircraft [219], need to be studied, tested, trained for, and implemented to ensure safety and consistency.

It falls again to the Solution provider to lend assistance to the customer's journey of ramping up their proficiency, as well as expanding their operational capability in the early years of the new Solution. Responding to technical queries, assessing risks, and approving changes from how the aircraft was originally intended to be used is an essential service to be performed to qualify the aircraft to the customer's operational concept, and expand their 'envelope of confidence' in the new aircraft and the Solution.

[34] The Royal Australian Air Force, as part of its Plan Jericho initiative, acknowledged that it hadn't always kept its operational tactics and procedures up-to-date with the technology it was using, retaining conservative navigation procedures even though their updated aircraft didn't require them. Whilst not a safety issue, it wasn't the most effective use of the technology made available to the Force.

24.5.4 For the Solution provider

The Activation Segment for the Solution provider takes on many facets, including:

- **Logistics:** Executing and improving the logistics chains for an aircraft
- **Early troubleshooting waves:** early issues that need to be worked through – whether technical, organisational process, data access, or another issue in the Solution ecosystem that needs to be sorted and bedded down.
- **Early reliability issues:** Early 'bathtub curve' issues need ironing out. Parts that may wear out quicker than expected, or problems that did not manifest during development and testing, especially with the newer aspects of the aircraft system, need close attention to resolving.
- **Enhancing provider proficiency:** Particularly an issue in the professional domains (such as engineering) where formal Type-endorsements are not institutionalised. Special attention is required in raising and sustaining a level of organisational knowledge, experience and competence in dealing with issues specific to the aircraft and the customer environment. This is often referred to as a knowledge management or organisational capability challenge.

24.6 Entering in-and-out of steady state

The aim of this segment-cycle model is to map the segments towards attaining a steady-state Solution operation. However, how does one know that 'steady-state' has been attained?

One definite sign is whether the operator is prepared and assured the aircraft can be used on a routine basis, in the way that it was originally intended. This is an accomplishment of both the continued availability of the aircraft (and its inherent functionality/capability) and the inherent and sustained proficiency of the key organisations involved in the ecosystem.

However, arriving at a steady-state is something more observed in the passing, rather than something declared before the entering. In addition, it's not so much a destination or result of a process; rather it is an expression of Solution state or an indication of its 'pulse'. This means the Solution may move back again into a transient-state.

This is particularly so if major changes or significant crises are encountered, and where the Solution ecosystem must forge deeper levels and lines of resilience, and adapt to a significant step-change in circumstances. Again, once that major change has been embedded, the Solution enters into a steady-state once again.

24.7 So what?

A steady-state Solution doesn't come to exist on its own – it takes careful planning and execution to develop a sustainable, valuable and effective operation. Poor foundations lead to poor Solutions (without much drastic efforts to change), and thus understanding these essential segmented fundamentals is essential to properly develop, manage and lead a Solution into the condition that is intended. While existing systems engineering and program management lifecycles certainly provide some level of insight – and a part of a methodology for devising, developing and deploying Solutions – they are not overly cognisant of the nuances of Complex Integrated Solutions, such as the development of an ecosystem, or the development of organisational proficiency. Thus, this new 'lifecycle' concept is a useful addition to any CIS management methodology.

Part V

A search for a new Embedded Engineering Function archetype

CHAPTER 25

Towards Transfiguration

The Conventional Embedded Engineering Function

25.0 Going another level deeper

This study has so far examined the conceptual building blocks behind Complex Integrated Solutions, identified some context, defined scope and terms, examined some case studies, and put forward a series of principles or core-logic suppositions that assist building a management methodology for Complex Integrated Solutions.

However, this study now changes-track and veers into a more detailed matter: the form of engineering in the in-service environment. Why? To develop a sustainment-focused Complex Integrated Solutions management methodology, there's also need to understand and appreciate the unique role of engineering, and in this instance, the Embedded Engineering Function (EEF) concept.

One of the things learned from the case studies was that in both cases, the conventional approach they had used to build their Embedded Engineering Functions (and indeed aspects of their broader Solution's) were not well aligned with the dynamic and complex demands their respective businesses demanded of them. As has been seen, such Solutions seek to fulfil customer's business needs; however, they're achieved by some highly technical means, the complexity and criticalness of which requires the presence of an Embedded Engineering Function, but one that is aligned to the nuances of such a Solutions paradigm.

Thus this chapter explores the reasons why this study embarks on a process of reconceptualising the Embedded Engineering Function, a veritable metamorphosis of engineering: to lay down a more comprehensive understanding and set of principles useful in devising and managing an Embedded Engineering Function within a Solution-like environment.

25.1 The Embedded Engineering Function revisited

This concept was introduced briefly back in Chapter 5, and while not normally called by this name, can be readily found in various forms across most aircraft operations organisations. The EEF is found as a group or unit(s) entrenched, structured and devoted to the operation of an aircraft fleet. Whether it is devoted to just one aircraft type or multiple types, the EEF is one of the organisational units focused on enabling a flight operations organisation to go flying[35].

However, seeking to specify its exact role and modus operandi is not something that's always clear or articulated in lucid terms. Because it's a clearer regulatory requirement than as a business practise, trying to pin this concept involves some higher level thought.

25.1.1 Finding the EEF

It's also not helped because trying to 'find' the EEF in an organisation is not always straight forward. Consider Figure 80 and the various locales of the EEF in each case study:

- For case study one, it was mostly in the 'Engineering Unit', but elements were also in the Logistics Unit, and (not seen in the diagram), and element of oversight was also conducted by the customer's own Chief Engineer who held ultimate authority and control over the Milvus
- For case study two, the EEF was enmeshed in the Fleet Management Group as Technical Services, but with other parts of its role spread out with the Maintenance Standards unit as well. The Fleet Management Group was composed not just of an EEF, but was an organisational department that also conducted maintenance, logistical and execution operations.

[35] There are of course many others, from flight operations support groups that do things such as generate flight plans, to training operations groups, and operational standards units, though to air-side logistics units to ready a flight, and, of course, the maintenance and engineering units that ready an aircraft. This point is merely to identify the context of an EEF.

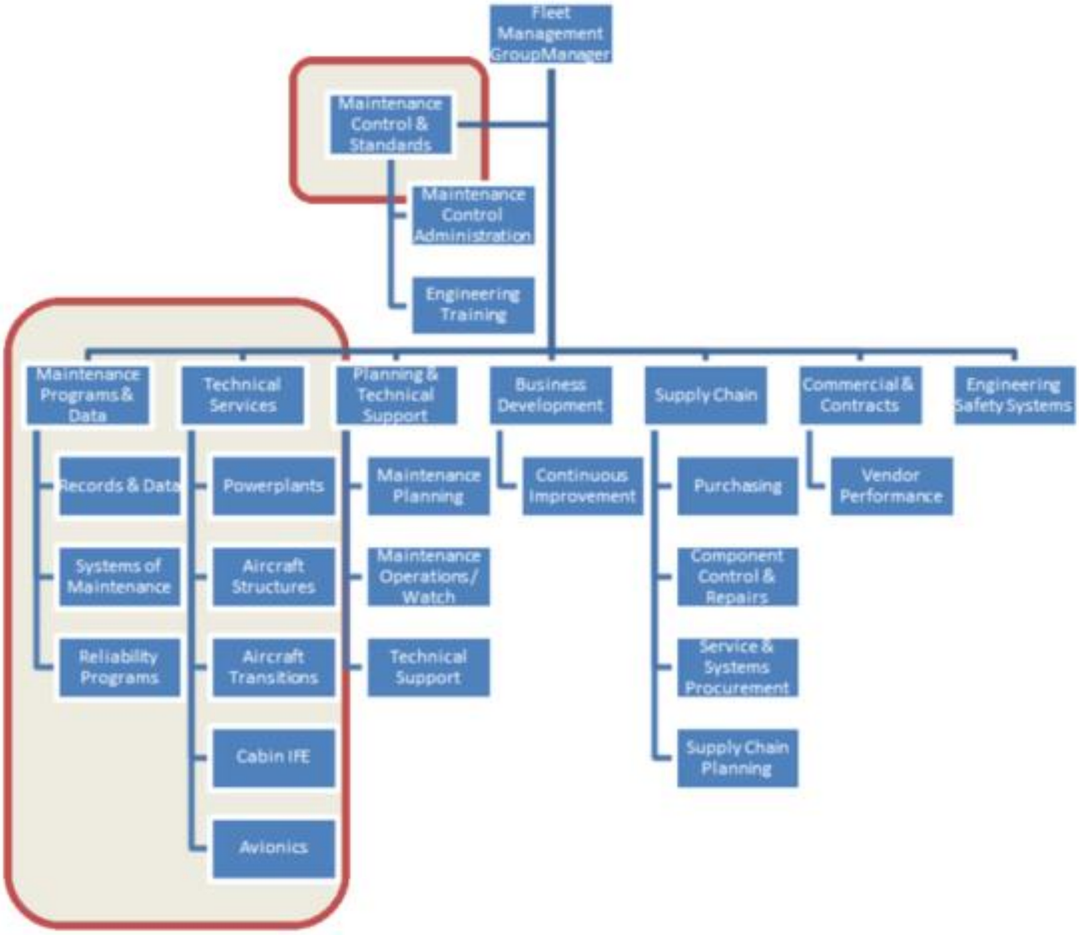

Figure 80: Finding the EEF in case study two's Engineering Community

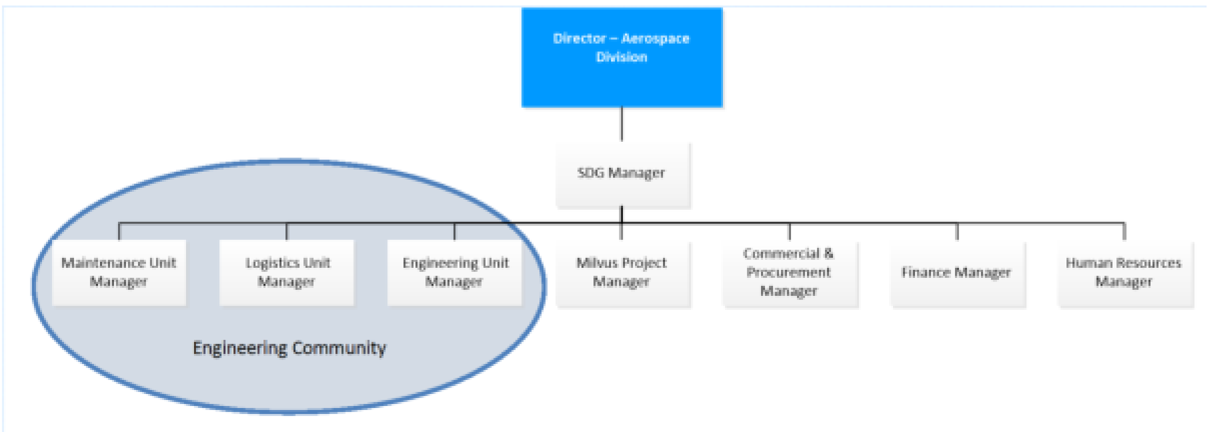

Figure 81: The Engineering Community in the Milvus case study

25.1.2 Conventional engineering & maintenance organisation structures

In a more broader sense, using references such as Kinnison [63], a conventional EEF concept is enmeshed in the maintenance division of an airline, which is generally composed of:

- Maintenance Planning & Operations Control
- Maintenance performance (actual hands on maintenance)
- Supply & repair chain management
- Technical services/Professional engineering outfit (often broken down by key aircraft functions, namely structures, mechanical systems, engines, and avionics)
- Program evaluation (often incorporated or connected with Engineering).

In such a context, the EEF is found in Technical Services and Maintenance Program Evaluation aspects of such an organisation (namely Reliability and Maintenance Program control) – those elements involved in defining the actual technical management policy for the fleet.

25.1.3 A key question

However, this search for the EEF raises an important point. The EEF is a specialised, professional and knowledgeable unit, yet it's one that does not hold responsibility for:

- scheduling/planning maintenance accomplishment
- actual accomplishment of maintenance work
- other efforts to enable the accomplishment of maintenance (such as purchasing and provisioning of parts).

It's an organisational function that fits and contributes to a broader organisational effort to technically 'enable the fleet' (i.e., ensure its upkeep and availability for flight operations). But given that the EEF and, for that matter, professional engineers don't perform hands-on maintenance, what is it they do?

25.2 Learning from the case studies

Understanding the unique role and work program of the EEF is something that can be explored by learning from the case studies. So what is it they reveal?

There are five key areas to be examined:

- Engineering and the engineering community (differentiating 'engineering')
- The wide field of responsibilities
- The work program of the EEF
- The core notion of the conventional EEF
- The lack of an organising concept in the Solutions context.

25.2.1 Differentiating the EEF from other 'engineering' formats

The first point is that the EEF sits at the top of an oversight and control regime that manages the physical configuration of the aircraft under its jurisdiction, and where there is some level of professional engineering input and 'leadership' (from a discipline and product governance perspective at least). Both case studies reveal a pattern whereby the Solution provider operates on three levels of engineering disposition, as reflected in Figure 82.

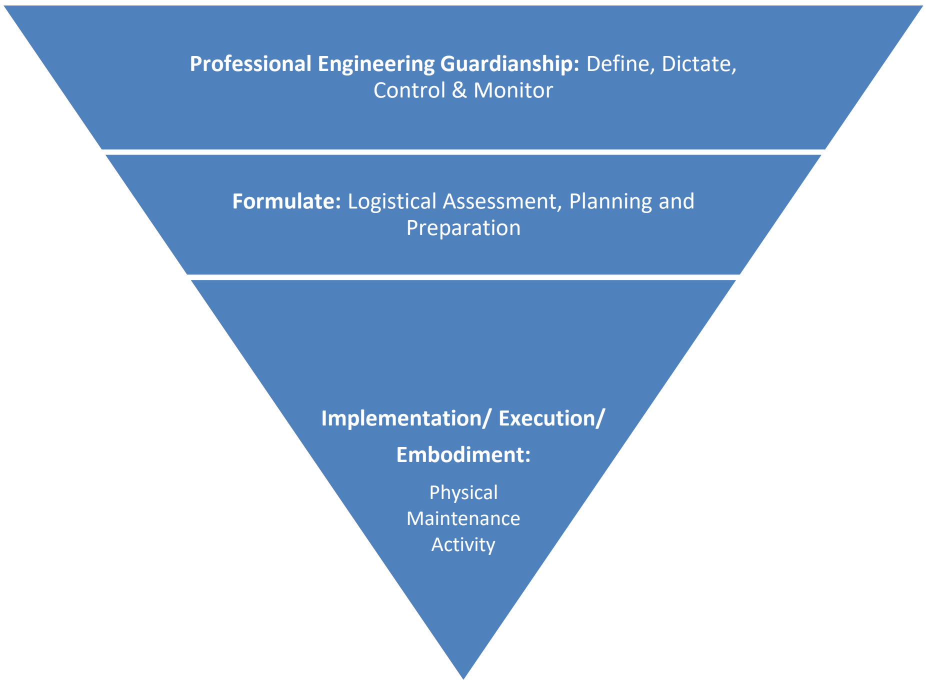

Figure 82: The engineering community and its various responsibilities, and disciplinary-directed by a professional engineering staff

Much of a fleet management Solution provider's organisation is either involved in:

- **formulating** maintenance activity, such as planning, coordinating, or advising
- **implementing** maintenance instructions as defined by a professional engineering post
- **guarding** the integrity and effectiveness of the 'complex of aeronautical systems' that is used by an operator to conduct its aviation-related business.

These three formats of work represent the presence of a broader engineering community that makes up much of a Solution provider. Each format needs to be clearly understood as each presents their own sets of challenges, and needs their own particular mastery of skills and knowledge. The implementation format requires skilled and qualified tradespeople with the necessary practical qualifications to perform and embody maintenance into the aircraft, an action that involves physically interfering and altering the aircraft. The formulation format requires tracking, researching, planning and preparation for such physical interventions; however, this is done using Technical Management Policies, such as maintenance schedules, maintenance task-cards, and that has been set down by another agency (the EEF). It's highly aware of the continual tension between production-and-protection/schedule-and-safety and becomes an important link in the chain between operational needs and safety requirements.

The final format, guardianship, is the domain of the EEF. It engages in a body of work that embodies a sense of technical *guardianship* and whose efforts are highly intellectual in their nature[36]. Instead, the EEF is engaged in working through matters that are of a more fundamental nature, and less formulaic in style. It's a work program that calls for deeper levels of problem-solving, analysis, professional judgement, and higher-order btechnical knowledge and understanding.

25.2.2 A wider field of responsibility

It's important to note that this sense of guardianship isn't just restricted to the physical aircraft. Rather, it's involved in controlling the integrity of the critical systems and technology that form the 'aeronautical systems complex' that is used by an operator to conduct safe flight operations. These can include control over:

- Fleet of airborne vehicles (aircraft)
- Training devices
- Training data packs (for devices)
- Authorised equipment for the aircraft
- Weapons and other payloads cleared to be fitted to the aircraft
- 'Approved data' – including publications, training materials, formal specifications, maintenance program, design data, logistics information (which forms the basis of the Technical Management Policy for this aeronautical systems complex).

25.2.3 EEF work program

So what is the work program of the EEF as seen in the case studies?

In contrast to the 'unidirectional' nature of product design engineering, the EEF has a multi-faceted program of activities, including things such as:

- Publishing and maintaining the Technical Management Policy
- Data management (such as operational records, defect reports, log books and deferred unserviceabilities)
- Technical investigations
- A rolling program of reliability analysis
- Maintenance program development (especially in light of investigations, reliability analysis, or other information provided from OEMs)
- Developing (or at least oversighting the development of) repair schemes
- Management of modification projects

[36] Not that that the other two formats are thoughtless – they just involve a more formulaic approach to the challenge. Neither is it to suggest that the EEF is 'better' than the other formats of activity in this engineering community; it's merely different

- Responding to technical questions and queries from other aspects of the Solution/sustainment community, such as maintenance planning or maintenance implementation (e.g., question about how instructions are interpreted)
- Controlling and tracking the configuration of the aircraft (including what LRUs, repairs, modifications are installed/embodied on the aircraft, and the maintenance program implications of those).

It's a wide range of activities that fit under three key workstyles that in turn reflects the nature of a conventional EEF: a *specialised technical control and response unit*. These styles are:

- Aggregate & Assess
- Respond & Coordinate
- Control & Dictate.

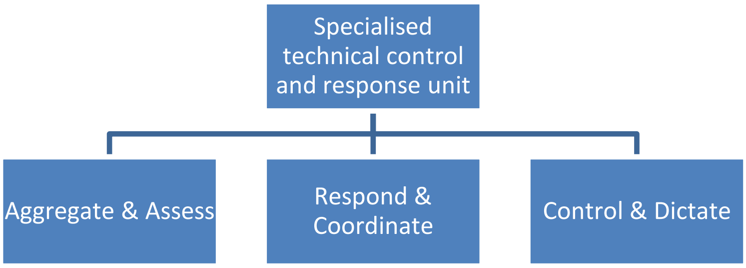

Figure 83: Conventional EEF work program

25.2.3.1 Aggregate & assess

The EEF has a program of acquiring, assessing and disseminating significant amounts of data and information pertaining to their fleet. Most comes through highly recognised and visible channels such as manufacturer publications, EEF investigations, official memos, controlled databases and data collection sources as specified by the quality management system. This includes:

- Reviewing airworthiness instructions and directives from manufacturers and regulatory authorities to see if they apply to the fleet (and any implications thereof)
- Operate a program of reliability analysis to ensure that the maintenance policy for their aircraft types are both effective, as well as identifying opportunities for improvement
- Undertake investigations into defects and recurring issues with the fleet, both to identify solutions, as well as understand any potential safety deficiencies in the aircraft's design.

25.2.3.2 Respond & coordinate

The EEF has a response and external request accomplishment component to its work program, which includes the capacity to:

- Respond to the flight operations group with advice to queries (on short, medium and long-term horizons)
- Provide engineering and design services and support to upgrade projects, and some cases manage them
- Respond to the maintenance implementation operation with advice concerning out-of-normal-limits situations, as well as devising of repair schemes as required.

25.2.3.3 Control & dictate

This is where the EEF publishes and promulgates the Technical Management Policy for the aeronautical systems complex used by the operator. This term covers the current and valid range of information, instructions, standards and requirements that dictate the use, operation, maintenance and overall definition of the aeronautical systems complex (namely, the aircraft). They're authoritative and exclusive in nature and include:

- The fixed maintenance program
- The instructions and data used in performing maintenance
- Flow-down into the maintenance planning group additional maintenance requirements that need to be performed (such as incorporating additional airworthiness inspections or modifications)
- The authorised parameters the aircraft is permitted to operate in – the 'safe' envelope.

25.2.4 A core tenet

The EEF represents a crossroad of information, requests, demands and activities, all aimed at controlling, protecting, preserving, and occasionally enhancing the condition of the fleet. They are ultimately noetic taskings squared at ensuring the ongoing safety, reliability, availability and end-user versatility of the aircraft fleet. It's a pursuit that can pursued by various team sizes, from a small group of less than a dozen people, to instances that may involve more than a thousand (for very large and complex operators).

What emerges from this list is the core tenet of the EEF is an organisation: that it's a *centralised, specialised technical control and response unit*. The EEF serves as an *authority*, as well as *service desk* which responds to requests. Much of the conventional EEF model is driven by external prompts triggered by other groups in the aircraft sustainment network or community, and it is the role of the EEF to provide an expert, insightful, and actionable response. In all, it possesses a significant role in supporting all the other sustainment functions that ensure an aircraft is ready to operate safely and reliably.

25.2.5 It wasn't enough

One key observation from both case studies underpins this entire Part of this study: that the originating organising concept of the EEF in both cases was not sufficient, and required a change to the form and shape of the EEF. This study frames this as a traditional or *conventional* approach to organising and running an EEF – a default set of ideas about how an EEF should be structured, including the organising principles (or lack thereof) that it's often built upon.

25.3 A default organising concept

To counter this default, conventional archetype, this study seeks to fashion a new archetype that is relevant for a Solutions paradigm. However, to do this, it's important to further understand what is meant by a conventional EEF be examining some its fundamental characteristics.

25.3.1 Finding a new archetype

In the quest for a new EEF archetype that is CIS-aligned, this study sets up a somewhat artificial construct, namely that there are two paradigms at play which dictate the phenomena observed:

- **A conventional paradigm**, where the management methodology for the EEF concept is a default archetype, passed down/around by tradition, and where there doesn't seem to be any viable alternative
- **A Solution-aligned paradigm** that drives Solution providers to think deeper about the EEF and its management methodology, and where a default response means the Solution-provider cannot operate at peak performance.

It's artificial because this study does not set about to establish the veracity of these two paradigms; they're crafted to illustrate a point, but are not entirely developed from a wide, factual base. They're effectively assumptions posed to serve a pursuit of clarity; the notion of a conventional EEF is but a stereotype [220][37]. Regardless, however, it's a useful device to set up a juxtaposition that highlights some new ideas on an EEF concept that is more acutely aligned with the Solutions paradigm.

25.3.2 Characterising a conventional EEF

So what exactly is meant by a 'conventional' EEF archetype? How can it be characterised beyond the scope of responsibilities and key routines? This question is best viewed through the lens of the service posture framework presented in Chapter 23 and adopting it into the EEF context.

[37] Interestingly, the term 'stereotype' comes from "French stéréotype (adj.) "printed by means of a solid plate of type," from Greek stereos "solid" (see stereo-) + French type "type" (see type (n.)). Meaning "a stereotype plate" is from 1817. Meaning "image perpetuated without change" is first recorded 1850". This is a perfect illustration of the description of a 'conventional' approach to the EEF – an archetype perpetuated without (or with little) change.

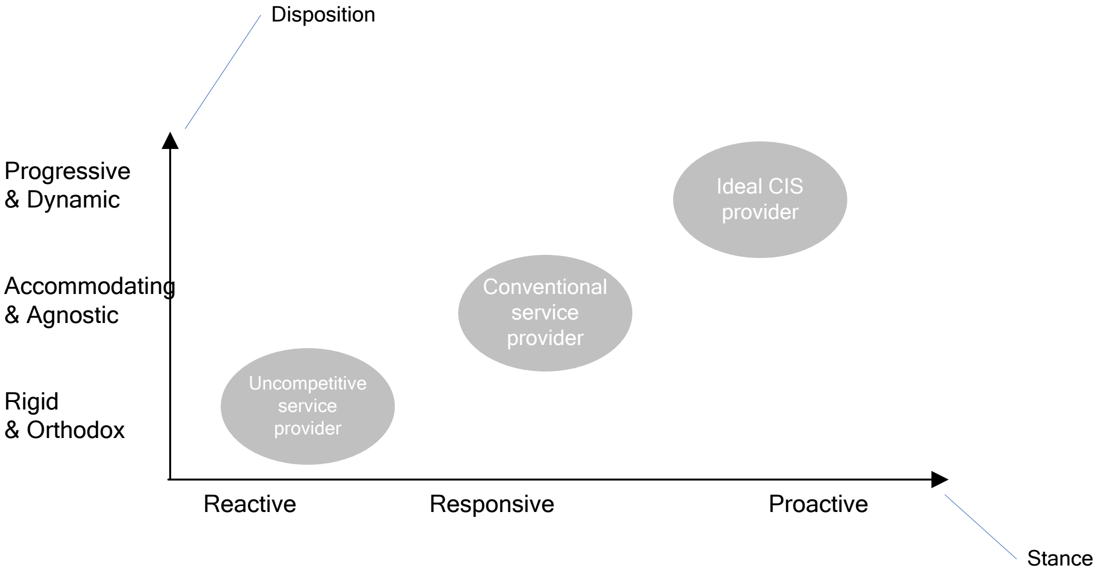

Figure 84: The framework of service posture as presented in Chapter 23

This framework, created to illustrate the service posture of Solution providers (and their respective service programs), helps visualise the stereotypical conventional EEF – located in the middle of the posture framework. To describe a conventional EEF as being 'reactive' is unfair, with 'responsive' a more fitting title, especially given the range of outputs they're prompted to generate by stakeholders. However, their disposition could be said to be passive – not reactive, but submissive to the context in which they operate, rather than exhibiting a more dynamic and transformative effect on their constituent 'clients.'

25.3.3 A product-centric archetype

There is another key characteristic of this stereotypical EEF – it espouses product-centric thought. This is exhibited through several, specific traits that a conventional Embedded Engineering Function *tends* to lean toward. These include:

- **Discipline-focused:** generally exhibiting a functional structure built around technical and product specialisations, rather than service streams.
- **Emphasis on working on detailed technical challenges**: Whilst working in a context of operational and business problems, the EEF finds its strength in a focus on technical, often physical engineering matters, and think and talk in such terms.
- **Respond to external prompts at interfaces:** Whilst the EEF is responsive, it's to prompts from existing, formal linkages with other units in its purview of responsibility (e.g., flight operations group, maintenance providers, logistics providers) in a strictly procedural and formulaic sense. It typically 'awaits' to hear from other units, rather than reaches out to them. It reflects a more

automated, systemic approach to organising, rather than a more organic, service-driven approach – in other words, a more transactional relationship.

- **Solves problems with technical solutions:** As a veritable brains trust, the conventional EEF uses its traditional technical tradecraft to solve problems, rather than considering other non-technical approaches.
- **Emphasis on assets:** The conventional EEF is deeply rooted in a product-centric worldview, which places a physical product or system at the centre of its thought-process.
- **Emphasis on technical excellence as end-goal:** The definition of success and achievement is bound up in the idea of delivering technically accurate and superior solutions. Such accuracy is, of course, paramount. However, on its own, it can distort the EEF from seeking to help its constituent clients reach their own sense of success.
- **Governance is focused on the integrity of functional discipline:** The EEF's leadership structure and accountability routines are built around ensuring the quality of the technical outputs, such as decisions, instructions, and directives
- **Highly process and procedure driven:** The EEF exhibits an overriding appetite for compliance above providing efficiency or effectiveness for the customer/operator. Embedded in this is an emphasis on performing tasks of a largely technical nature, rather than of a service nature.
- **An emphasis on Platform management:** In a similar vein to the emphasis on assets, the management structure and methodology of the EEF is focused on the aerospace platforms/aeronautical systems complex the customer uses.
- **Oversight 'cost-centre' activities:** An operator can easily frame aircraft sustainment activities as a 'cost centre', an assertion that can carry negative connotations. One such connotation is an emphasis on continually lowering costs. This is in contrast to seeing the EEF as an agency that helps lead efforts to improve the value aircraft, and other elements of the aeronautical systems complex, present to the operator (such as improving reliability profiles or enhancing the sensor payload abilities of the fleet).
- **A tendency to be inward-looking:** A stereotypically conventional EEF places greater priority on controlling what's in their domain of responsibility.

These are not at all bad attributes; in fact, many of them are paramount and critical to the task at hand, with the devotion to quality and unrushed consideration part of what makes an EEF valuable to an operation. And, has been already stated, does not reflect all EEF's; each EEF in the real-world is likely to exhibit its own strengths and characterisation that is slightly different to others. However, this characertisation does help fill-in this stereotype of a conventional EEF, and form characteristics that are contrasted against a Solution-aligned EEF archetype in Chapter 28.

25.3.4 What's different?

Throughout the course of the study, it became clear from that the Complex Integrated Solution/Solution Delivery Unit/Fleet Management Group was not optimally served by *conventional*, discipline-based functional organisational structures of the EEF. This includes that:

- What the EEF was asked to do was beyond the traditional functional breakdown, with demands on it beyond that of a 'brains trust' or 'output' system
- The value that engineering brought, and the demand placed upon it, was more complex that this 'brains trust' concept
- The nature of what engineering could bring wasn't fully reflected in the functional structure.

The benefits that the Solution ultimately delivers to the customer enterprise go beyond providing an in-the-moment operational capability (one that is normally defined by a Solution success metric), but to solving other problems to which the customer needs a response. Much of this is in the domain of the EEF, including other non-performance-based[38] efforts such as a readied capacity to pursue capability enhancements, operational enhancement advice, and technical publication support. It thus raises the question: how can the EEF concept be reimagined to go beyond this conventional model?

It's a question that's not just relevant for formalised or out-sourced 'Solutions.' Any EEF operation, whether a part of the operator organisation, or part of an outsourced approach, whether driven by a clear performance-management regime or driven by a corporate expectation and demand for 'something beyond the norm' will find this question of leading importance.

25.4 Why a quest for an engineering metamorphosis?

But why does this question need to be asked at all? And does it require a special focus?

25.4.1 A major problem or a default concept?

First, this question of reconceptualisation does not reflect a fundamental 'ethical' issue whereby aircraft safety is in jeopardy. Rather, it comes from 'friction' – suboptimal resistance that promotes misalignment – identified in the case studies, where the EEF is not served best by conventional, discipline-based functional organisational structures. This study identifies that this friction is due to three main factors that have made the conventional stereotype a default concept.

25.4.1.1 Regulatory impacts

Airlines have had some sort of structure to their engineering & maintenance operations for decades, and militaries too, have had their own technical outfits. However, much of this conventional EEF archetype is a by-product of a concept reinforced by regulations, particularly CAMO & Maintenance Organisation strictures. As regulatory compliance is a major fundamental in aviation operations, meeting these requirements becomes the de jure driver of the organisational form an EEF takes. As such, the conventional EEF stereotype looks like the minimum safety standards imposed by a regulator, rather than a form that reflects business needs.

25.4.1.2 A concept not settled

As such, the concept of the EEF might have some rigid constraints imposed on it; however, it's not necessarily a concept that is fully settled. It's also a concept that has not been overly supported by published management thought.

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[38] In the sense of a performance-based measure for contract purposes. This is not to say, however, that these aspects are not time-sensitive or don't require good organisational performance to deliver them.

There exists much commentary, frameworks and 'management thought' (often by engineers) for product development engineering, notably deeply entrenched with product-centric thought. This study, however, seeks to make a contribution to management thought on in-service engineering to redress the dearth of material[39] on new ways of rethinking the EEF and how it can be managed from a pragmatic business standpoint

25.4.1.3 A concept ripe for greater cohesion

Whilst it's a pursuit rooted in practice, engineering in the in-service environment (particularly the EEF) has never properly been explained for 'outsiders' (and arguably even 'insiders' cannot articulate it coherently, without jargon). Ask people in the Boardroom, let alone on the street, and answers would be primitive at best.

Engineering isn't always visible, but it 'lurks behind the scenes,' protecting people, property, and ultimately, interests (whether corporate, individual, or societal). Its effects continue to be seen, even if not recognised or appreciated as such. It's an intrigue for the greater good of technical proportions. However, this lack of explanation leaves the EEF concept in a conventional, perhaps obscure state. Thus, there is scope to more accurately define and expound the role and value of the EEF from first principles.

25.4.2 To bring in a unique angle

There's another reason, too, for revisiting the notion of the EEF. This Part is not devised because there are no organising concepts available, or that what currently exists is entirely deficient. What this Part presents is a conceptual 'upgrade' that puts a more pronounced sense of mission around the in-service engineering endeavour. In particular, it does so to reflect the nuances of fleet-focused Complex Integrated Solutions. As has been seen, such Solutions seek to fulfil customer's business needs; however, they're achieved by some highly technical means, the complexity and criticalness of which requires the presence of the Embedded Engineering Function. Thus, this Part seeks to lay down some understanding and principles, taken from this study's research, that would be useful in devising and managing an Embedded Engineering Function within a Solution-like environment.

25.4.3 Transfiguration, not obliteration

This quest for a new concept is framed as being a *metamorphosis* because it's not about obliterating a conventional or traditional concept; rather than fully destroy the original concept, it transforms the existing elements to become a better version of itself. Further, this is about rejuvenating the engineering organisational form in the in-service environment, rather than the sustainment discipline (i.e., the scientific and mechanical principles used by engineers). As such, this quest for an engineering metamorphosis is about transfiguration, not obliteration.

[39] Of course, human factors and safety matters have helped propel the concept forward.

25.5 Pursuing a metamorphosis

So, how will this Part pursue a reconceptualisation of the Embedded Engineering Function?

The end-game is to present a new class of a Solution-aligned EEF archetype, referred to as 'The Sentinel.' It's a set of organising principles, frameworks and ideas that take this entire study's quest for a new management methodology for sustainment-focused Solutions to a greater depth, covering the unique role the EEF contributes to Solution success.

To achieve this, this Part is broken up into 4 Chapters:

- **Towards Transfiguration** (this chapter)**:** to articulate why there is a need to seek a new form of the Embedded Engineering Function as part of a quest for a management methodology for Solutions
- **The Fifth Manifestation of Engineering** (Chapter 26)**:** Exploring and putting forward an alternate concept of engineering that addresses shortcomings in the current product-centric definitions and conceptualisation of engineering that makes in-service engineering seem less congruent as a legitimate engineering pursuit
- **Airworthiness Revisited** (Chapter 27)**:** This chapter turns aside to one of EEF's most important pursuits – the management of airworthiness. It puts forward some observations and insights taken from the case studies about the nature of airworthiness management, which itself plays into the management methodology of the EEF.
- **The Solution Sentinel** (Chapter 28)**:** The presentation of key principles and frameworks that paint a new archetype of a Solution-aligned EEF.

25.6 Transfiguring the engineering concept

25.6.1 A practical note

When considering this discourse, one will notice that there is seemingly a large oversight – the role of engineering in conducting major upgrades, modifications and redesigns. This form of engineering does take some specialist knowledge and experience, given changing a highly-optimised platform requires extra care and potentially a great deal of reverse engineering. However, what this study looks at is the professional engineering operation resident with a flying and associated fleet management operation. Also, major modifications and upgrades are generally a form of new product development (or at least a new aspect to a product redevelopment).

It's also important to consider that this notion of 'conventional-versus-transfigured' class of EEF is an artificial construct. Of course, most engineering organisations are all different and ascribing them the class of a being a conventional EEF can be misleading. Some EEFs, even if they do exhibit these stereotypical EEF traits, may find that suits their particular circumstance. However, it helps make clearer the distinctions between a default EEF archetype and one that is worked-up to be more fitting for a Solution-driven situation.

25.6.2 A pursuit

Even the presentation of the Solution-aligned EEF in Chapter 28 does not specify exact structures or forms that all EEFs should adopt. It's merely principles that help form a management methodology for that type of outfit and is in line with this study's ultimate pursuit of cogency.

To that end, there is an important question that must first be considered, and returns to where Chapter 6 left off: namely, what is a concept of engineering that better encompasses and explains operations such as the Embedded Engineering Function? This is explored in the next chapter.

CHAPTER 26

The Fifth Manifestation of Engineering

Apprehending the True Essence of Engineering

26.0 In search of a new understanding

Chapter 6 ended with a key question: if engineering's primary modus operandi wasn't just about designing things, then what is engineering truly concerned with?

Because after reflecting on the role engineering plays in two in-service engineering case studies, definitions that claim engineering is 'designing and making something' simply don't suffice, nor represent complete expressions of the true nature of engineering. While it's true that many engineers do build and work towards something physical, there are many engineers whose work doesn't always take a physical form.

To further explore this matter, this chapter wades into the conceptual domain of *engineering philosophy*. Such a pursuit involves considering the big picture – not of a strategic situation, but something more abstract. It's an intellectual space that finds it intersecting with the scholarly field of engineering ethics, but that more specifically seeks to answer important ontological questions such as:

- What are the core fundamentals of the engineering profession?
- What qualifies (or disqualifies) something as 'engineering'?
- What is the purpose of engineering? What's its reason for being?
- What is the 'ultimate purpose' of engineering?

Whilst this chapter is philosophical in nature, it does exhibit a practical edge. It seeks to stretch wide-open this theme and seeks to answer *what is the true essence and character of engineering*? In particular, this chapter is concerned with the engineering *profession*, rather than the engineering *discipline* – a distinction that positions the engineer as a practising expert with a level of public recognition, rather than as a body-of-knowledge that can be studied.

In answering this question, this study asserts a new schema of definitions of engineering that frees it of a dominant emphasis on product-centric thinking and the activity of new product development. Ironically, however, this new schema does take inspiration from the field of 'design thinking.'

26.1 The nature of the endeavour

Taking the question of essence and character to another level is to consider the nature of engineering work itself. In the literal sense, most engineers don't build things; one would very rarely find an engineer physically using their hands in the construction or assembly of a product, widget or edifice (at least in a professional sense). Yet, engineers *are* highly involved in the construction of things that have been designed by issuing instructions to those who actually, physically construct, assemble or implement physical transformations. Engineering is primarily a *cognitive* and *directive* endeavour, not a physical one; yet, engineers do cause *effects* in the real world. Engineers are the 'brains' behind impressive arrangements, but such arrangements are only brought into being through the 'hands and feet' of other trades.

Thus, to assert that 'engineers design things' or that 'engineers build things' is not a complete understanding of the true, complex nature of the engineering profession, nor of the value, it contributes to society.

26.1.1 Going beyond things

Most definitions and explanations of engineering refer to the practice of organising the design and construction (and Vicenti would add 'operation') of any artifice which transforms the physical world to meet some recognised need. Vicenti is probably as close to any to a more thorough analysis of what it means to *engineer*:

> "Here I take "organize" to be meant in the sense of "bringing into being" or "get together" or "arrange". The first end, "design", has to do with the plans from which the artifice is built, as in the many drawings (or computer displays) of an airplane and its components. "Construction" (which I shall call "production") denotes the process by which these plans are translated into the concrete artifice, as in manufacture of the actual airplane. "Operation" deals with the employment of the artifice in meeting the recognized need, the related example here being the maintenance and flight operations of the airplanes of an airline [85]."

This study, too, asserts that engineering is something that ultimately goes beyond physical construction – something demonstrated shortly. Based on GFC Rogers' [221] definition of engineering ("transforms the physical world"), this could mean something physical but is also equally applicable to other realisations, such as the arrangement of people and information too. Software engineering isn't so much concerned with rearranging physical 'stuff' as it is concerned with the intentional transformation of data and information for the benefit of defined users.

26.1.2 A new definition: how did it get here?

To address these gaps often caused by product-centric thought, this study proposes a new schema of definitions. However, before presenting them, it's important to know how they were arrived at so as to understand the cognitive context.

The new definitions were arrived at after working through the following contemplations:

- A motivation to find a more encompassing working definition of engineering that made professional engineering activity in the in-service and Complex Integrated Solution space more congruent (rather than using definitions that seemed to contradict or failed to legitimise professional engineers working in a non-designing capacity)
- Personal reflections on the author's own professional experiences of the role of professional engineering in an operational environment
- Reflecting on the professional experiences of the author's engineering colleagues
- Reflecting on the definitions and works of engineering philosophy examined in Chapter 6
- Exploring the etymology and meaning of many different words, seeking phrases that would articulate a clearer meaning – in effect, 'wordsmithing.'

It was from this combination of effort that this new definition/concept set was derived. It's important to note that this derivation wasn't as rigorous as a full thesis on the topic – providing full derivation and justification of this view of engineering is undoubtedly a thesis in itself. In the context of this study on Complex Integrated Solutions, these definitions merely form a justified working-definition – effectively a mere assumption on which to base a more informed discussion about the role of engineering in the in-service environment.

26.2 A new state of affairs

So, where does this leave the question of engineering essence? What is an alternate concept of engineering that better helps explain the role of engineering in the Solutions space?

To help answer those questions, this study asserts a system of definitions that are more encompassing of non-designing engineering activities:

- Engineers are ***contrivers of a preferred state*** or situation achieved through scientific and technological means.
    - In the engineering sense, a **contrived preferred-state** is the *continuing existence of a preferred condition or circumstance in a defined domain or station, caused by the deliberate and intelligent arrangement of natural or technological elements, in a way cognisant of active and latent stakeholders.*
- Engineering is *the professional and intellectual discipline concerned with conceiving, defining, communicating, implementing, activating, and otherwise managing a* ***contrived preferred-state*** *whilst confronting complex impediments and atrophy that oppose that preferred condition.*
- Engineering is a diverse field, not just in disciplines, but in ***modes of engineering***;
- Engineering groups or teams are the manageable and visible units of in a firm that perform the function of engineering. They're composed of staff whose professional activities are **directed by professional engineers**, even though the entire group may be comprised of other trades or specialists who are not professional engineers. They may be involved in more than one mode of engineering at a time.

For the sake of brevity, these contrived preferred-state definitions will be referred to as the *CPS schema* or *suite*.

26.3 Breaking it down

26.3.1 Unpacking the new definition scheme

These sets of definitions and descriptions depart from 'traditional' definitions that are focused more on the activities of engineering, rather than its effect or its distilled essence. When seeking to understand or apply these definitions, there are many valid questions to be considered, including:

- Where does the concept of 'contriving' come from?
- What is the notion of 'preferred-state'?
- Why the reference to 'active and latent stakeholders'?
- Why the reference to 'complex impediments and atrophy'?
- What is meant by 'modes of engineering'?
- Do these definitions truly hold for all engineering activity?
- What are 'scientific and technological elements'?
- What does it mean for the professional engineer on a day-to-day basis?

This section seeks to explore several of these questions.

26.3.2 Why 'contrive'?

The word *contrive* can readily paint a sinister scene. However, the word itself is not a negative expression, and in fact, conveys some very laudable characteristics:

- to arrange a situation or event, or arrange for something to happen, using clever planning [222]
- to invent and/or make a device or other object in a clever and possibly unusual way [222]
- create or bring about (an object or a situation) by deliberate use of skill and artifice [223] .

This notion of 'clever planning' to 'bring about' a situation or event by 'deliberate use of skill' sounds similar to engineering. It's a word that, in the view of this study, neatly captures many of engineering's attributes of using creativity, imagination, analysis, methodical planning and validation for redirecting natural forces towards an alternate end. *Contrive* is also a verb, a term to express some form of action and energy, which again reflects the pragmatic orientation of the engineering modus operandi.

Contrive also suggests a 'brains-on, hands-off' approach, consistent with the intellectual formulation role (versus physical implementation role) of professional engineering. To 'contrive' something means to exhibit skilful manoeuvring and choreography, even when this involves issuing instructions and directions for others to implement.

This leads to an important reflection on the role of *intelligence*, given that engineering is an intellectual discipline, rather than a skill-based tradecraft. Perhaps an enlightening concept emerges from Harvard University Psychologist, Steven Pinker, and his definition of intelligent life:

> "using knowledge of how things work to attain goals in the face of obstacles [224]."

It's in this vein that *contrive*, the 'clever and possibly unusual way' of making things happen, again aptly describes the engineering approach. Even in the face of obstacles, opposing priorities or natural or social contradictions, engineers find a way to make something work effectively (without resorting to unverifiable 'tinkering').

26.3.3 What is 'state'?

State, also, is a word with various meanings, but the following are particularly pertinent to this notion of *contrived preferred-state*:

- a condition or way of being that exists at a particular time [222]
- The particular condition that someone or something is in at a specific time [223].

State is intended as a way of explaining a situation, a context, or a station of activity that has been 'bettered' due to a technological element and/or some form of scientific knowledge. A bridge betters a city's transport corridors; a high-functioning building betters its occupants and owners; a safe and effective transport aircraft betters the passengers and crew to move with high speed and assurance of reaching distant location.

In this instance, state isn't taken to mean purely the state – e.g., the health – of an asset or system (although this is certainly a part of it). Rather, state is a *social* construct.

This notion that state is a social construct is illustrated in Figure 85. At the core is some sort of 'engineered arrangement' – whether a system, a process, preparations or some other sort of 'engineered' intervention. Such an intervention emulates some sort of functionality – 'intended behaviours…based on a set of requirements regardless of implementation [225].' These 'system' behaviours can lead to benefits for users and other stakeholders.

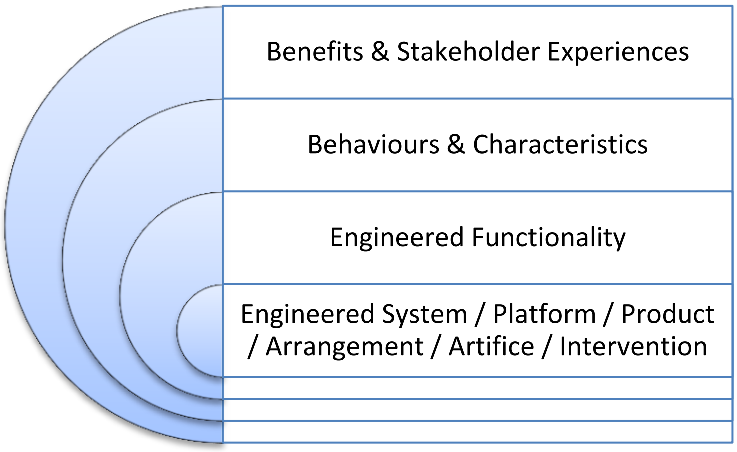

Figure 85: A contrived preferred-state value flow

It remains, however, that 'state' is a nebulous concept. It cannot be held in the hand, nor can it generally seen with the eye. It's something experienced at the social and noetic level – a 'sphere of betterment' due to engineering's involvement.

As such, it's difficult to draw a definitive boundary around just what exact estate (whether physical, mental, conceptual, or all the above) is under engineering's control or influence, and thus what the defined station is that holds that 'preferred state.' It's easy to draw a boundary around an aircraft or a bridge; yet putting a circle around the 'necessary elements' to make safe flying a possibility is more open-ended.

In practice, one would probably still look at 'definite articles' such as aircraft, bridges, or software suites; however, one would also be well advised to adjust their mental lens to see their work in terms of a *preferred state*, rather than limiting it to just a physical object.

26.3.4 Why a 'preferred condition'?

The term *preferred* comes from some important observations made by those in the world of *design* (of the non-engineering variety such as visual, business, service, or other 'humanities-centric' approaches). It's a world where *design* is not just a verb, but a noun, and where it's just as much a profession, a skillset and a technique as it is a style of thinking.

Nobel Laureate Herbert Simon and Milton Glaser, the artist behind the prolific "I love New York" design (who is perhaps inspired by Simon), express the concept of *design* in the following ways:

- "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones [226]"
- "Design is simply moving from an existing condition to a preferred one [227]."

This view of a preferred situation is also expressed in the idea of *existence*. Keith Yamashita puts it this way:

> "Design is a method of imagining something that does not yet exist, and then rearranging all the elements required to make it a reality [228]."

When design is viewed as something beyond the blueprinting of physical things and instead is understood as the realisation of a preferred condition, it adds a new dimension to the role of engineering. Whilst these design definitions were articulated in a non-engineering context, they offer a refreshed perspective on the role and strategic modus operandi of engineering, potentially yielding a more instructive view of the profession. It suggests that both the aim and the result of what engineers do cannot be quantified alone in the products or process outputs they attain, a fact that opens up engineering as being more encompassing of broader technical efforts beyond designing and manufacturing.

It's from this perspective that the notions of 'contrived,' 'preferred' and 'state' can be brought together.

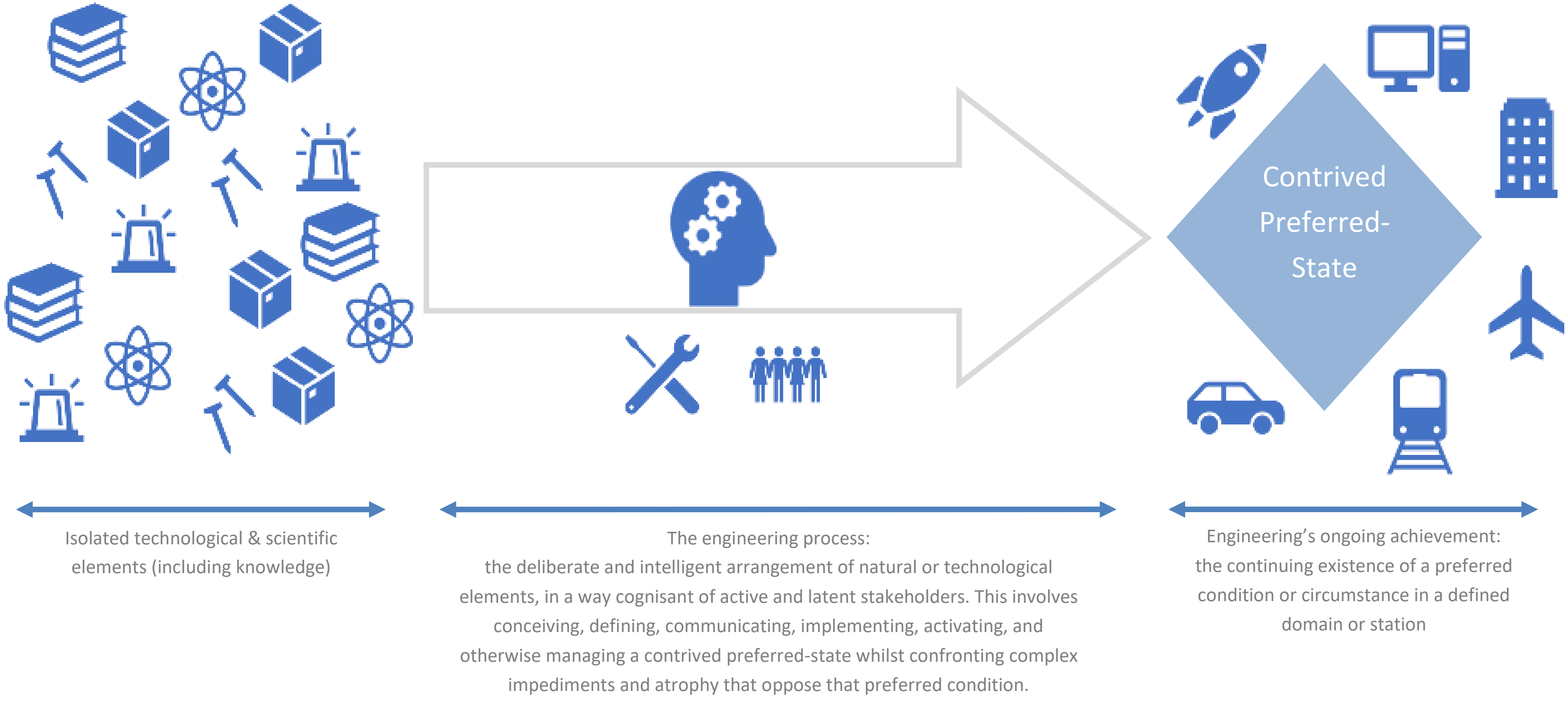

Figure 86: Engineering as a human endeavour of moving from an existing situation to a preferred one

26.3.5 Contrived preferred-state

All the above leads to the core concept of this new definition suite: ‘contrived preferred state.' It’s a concept that seeks to express the following qualities:

- Inherent characteristics and attributes of some transformation, arrangement or intervention, experienced at the point of demand or need
    - Engineers don’t just build things – they apply their minds to help create desired effects.
- Intentionality – something that happens ‘by-design,' and is not often found naturally occurring
- An emphasis beyond the immediate product, system or artifice, and instead to the espoused and emitted utility (the ‘halo’ of the product, system or engineered arrangement/intervention).
- Continued presence: a concept born partially out of Vicenti’s idea that engineers “organise” and “transform,” and by extension, they “bring into being [85].”

At a less-philosophical level, ‘contrived preferred state’ is best explained from the following perspectives:

- State is not just the artifice or arrangement that is at play – it’s the *potential capability* and power the customer or end user possesses.
- State is the intended potency and utility that the engineered arrangement was designed to give. It’s not just where the system or design is realised/exists – it’s where its inherent power is ready to be unleashed.
- State is expressed through many and varying characteristics, such as readiness, level of safety, at-call effectiveness or lethality, a particular cost profile, and so forth.
- State is ultimately understood in the experiential domain.

Contrived preferred-state might be best understood using an analogy of cell or viral cultures – organic, ‘living’ things that are cultivated outside their natural environment. They are ready, fertile, and operational – just not yet unleashed into an environment where they can cause major effects. Once unleashed on a cell population, however, their inherent power is brought to bear.

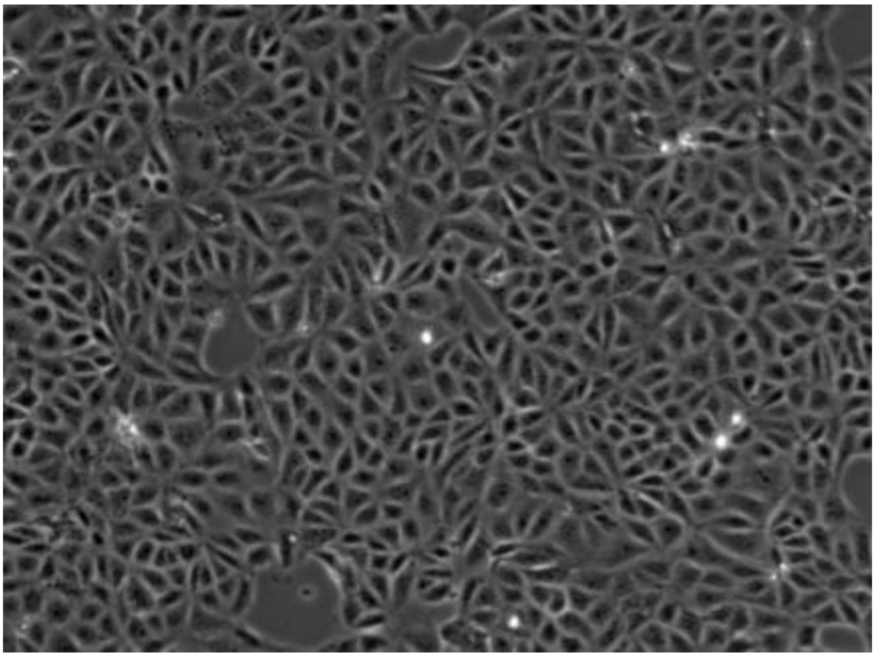

Figure 87: Cells in tissue culture as an analogy of 'state.' [Photo from http://ibidi.com/applications/technical-aspects-of-microscopy/cell-culture-surfaces/]

It's important to note that there is one further level to this CPS scheme; however, it is entirely in the domain of the operator or user. It's where the user has access to, and takes that engineered arrangement and uses it to create intended effects. This is the realm of *capability* (discussed shortly).

26.3.6 Complex impediments & atrophy

Because engineers are involved in the process of transforming natural and technological elements, they face a formidable foe – atrophy. As such, a preferred condition is not something that's always 'nature's default.'

Atrophy, along with other complex impediments such as stakeholder expectations, regulatory requirements, commercial factors, and the like, are considerations that will seek to oppose the longevity and continued existence of a system, arrangement or intervention. Even in software engineering, where code cannot 'deform' on its own, efforts must be expended to ensure that code remains valid, safe, and resistant to exploitations – not to mention ensure the software will continue to function on degrading hardware (or, when it's upgraded).

As such, there can be no abdicating responsibility for an engineered arrangement without loss of functionality or its preferred-state status. The engineer's efforts in design and production are 'wasted' if the engineering profession doesn't embrace a mandate to ensure the proper delivery of that preferred circumstance – and if it cannot be economically provided, close it down.

This concept is particularly pertinent given that engineered systems generally face many atrophying challenges, including decay of materials, knowledge, and essential resources. It's included in the engineering definition above for that reason.

26.3.7 Not walking away

Extending this concept of adopting a responsibility mindset – rather than a discrete task or job mentality – is the reasons why the word *contrive* was chosen over the term *devise*.

Devise was ultimately not chosen because of a relatively greater implication and emphasis on designing and development of something, compared to *contrive*. Of itself, it's an instructive word describing much of the engineering methodology. However, the term does suggest a convergence on a solution, before 'walking away' onto the next challenge.

The term 'contrive' does suggest more latitude for an open-ended, divergent and 'infinite game' approach to engineering, while also fully encompassing of design and development of physical objects. 'Contrive' can possess a meaning suggesting longevity and commitment – an ongoing effort to devise and maintain a certain state of affairs.

This logic is also important to understanding the distinction between 'contriving a preferred state' (an action phrase) with the more traditional assertion that engineers are 'problem solvers.' On initial inspection, both notions seem to be quite similar. However, this study contends that there are subtle differences in understanding that these phrases conjure in the mind. There is something singular about the term 'problem solving' in terms of the problem arena to be solved, the moment in time that the problem is solved, and the end-game that's sought. 'Problem-solving' is perhaps more precisely articulated as a skill-set, rather than the result of engineering's efforts. Contrived preferred state, however, can mean solving a need on a more enduring basis. Whereas 'problem-solving' can imply solving a specific conundrum at a particular point in time, unless that fix is absolutely irreversibly permanent, then it's difficult to assert that the problem has in fact been solved.

Contrive more expressively conveys a different mentality and approach to engineering than to the one that has been traditionally, and subtly, imbued into the engineering psyche – that once a project, construction, or design has been completed, it's time to move onto the 'next thing.' Whilst this is certainly true for certain *modes of engineering* (something discussed in more detail shortly), such as engineers engaged in the design and development mode, the CPS definition suite seeks to counter this time-bound mentality of the engineering profession. Instead, the notion of *contrived preferred state* implies the ongoing work required by different disciplines of engineers, operating in different modes, to maintain that preferred condition. In the collective sense, the engineering profession will rarely 'walk away'.

26.3.8 Mindful of stakeholder needs

This study puts an emphasis on being mindful of *active* and *latent* stakeholder needs. The notion of 'active-vs-latent' is to reflect that at the point of designing something, not all the stakeholders may be considered or be affected. However, once a system, arrangement or intervention is commissioned, those latent stakeholders may be majorly affected.

An aircraft in development on the ground poses little hazard to a community around the airfield where it is being built. However, the moment the aircraft begins flight test, the local community moves from being a latent participant in that situation to a more active one, even though they are not a principle beneficiary of that contrived state. Even though future passengers will become the customer of the future preferred operational state of the aircraft, that local community does need to have their interests for safety and environmental protection addressed as well.

In the derivation of the new CPS definition suite, the use of sentiments such as 'meeting stakeholder needs' was considered. However, not in all situations should all stakeholders' interests be met – there are often competing priorities where one stakeholder's interests must be considered over another. Perhaps one extreme case of this is the engineering of weapon systems; one stakeholder in the 'preferred state' of an explosive ordinance is the intended target. As such, being cognisant of stakeholders is important; however, this space then must refer to the realm of engineering ethics – itself an active intellectual space that would make a greater contribution to this question that this study can.

26.3.9 Why not an outcome?

It would be understandable to confuse the notion of *state* with the notion of an *outcome*. However, the concept of *state* was chosen based on the following logic.

An *outcome* is specifically isolated from the action or situation that caused it – it's an analytic construct that looks at the aftermath following some event or period of time. *State* is chosen because while it encompasses notions related to the term *outcome*, it is a term that is more descriptive of *presence* – a manifestation of something with useful, intrinsic qualities.

The notion of *state* is also more enduring compared to *outcome*. 'An outcome' suggests a result at a point in time. *State* can reflect something more immutable and intrinsic, although it must be noted that 'state' is the condition of something at a particular point in time and thus is not a concept entirely independent of time.

Thus, an engineer to be focused on creating a *preferred-state* more readily implies an enduring situation or arrangement that continues to meet a need. An individual or a group seeking an *outcome*, however, more implies actions during an episode with a clear start and end.

26.4 One final step

Because *state* implies a presence more than a power, there is one final conceptual step in this suite of definitions. Many names could describe it, but the notion of 'contrived-state-in-use' is reflected neatly in a term often found in military parlance – the concept of *Capability*.

The RAAF's definition is succinctly illustrative: "Capability is the power to achieve a desired operational effect." However, this definition continues by explaining that:

> "Capability is much more than just the aircraft or training personnel to operate equipment. Capability describes the optimum combination of the organisation, its personnel, collective training, major systems, supplies, facilities and training areas, logistics, support, command and management required to deliver a sustained effect, at the right time, in the right way, for an extended period [229]."

Capability, or the power to create effects, is something that is mostly executed beyond the realm of professional engineers; it's executed by users. Importantly, simply owning an aircraft, or some other system, of itself, is not enough to generate capability. Several military capability frameworks [28, 30, 39, 40, 217] describe how capability requires several readied inputs to produce a capability. Capability is attained when trained crews operate a system, using specific tactics, techniques, and procedures (TTPs), exploiting information and intelligence, under a regime of effective battlefield coordination and management.

Figure 88: From an existing condition, to a contrived preferred state, to customer/user capability

26.4.1 Not just an input, but a field of responsibility

Where contrived preferred-state is important is that it represents potential capability. In this definition suite, contrived preferred-state is not merely an input; it's a significant, interlinked *potential* that can be transformed by a user into an effect.

Rather than an input mixed with other ingredients, CPS is a circumstance where aircraft are in a readied condition, qualified for a wide-range of actions and functions, and possessing inherent levels of reliability and assured levels of safety. It represents something more akin to an *organ of capability*, an analogy based on the human body. The organs of the human body are distinctive biological systems of their own (such as the brain) that can be studied, operated on and often even operate (in a limited way) in isolation from other organs. Yet, on their own, they have little inherent utility. Only when each of the organs works together as a system of systems does the whole body operate in an orderly fashion.

This is a highly conceptual view. Practically speaking, it is much more manageable to consider systems, such as aircraft, a key ingredient to sortie generation, and where the engineer's role is segregated in various ways:

- Ensuring proper maintenance has been carried out
- Planning and delivering targeted aircraft fleet availability
- Support in the development of TTPs
- Additional logistics efforts to ensure the aircraft fleet meets the customer's operational need, among other responsibilities.

This ‘capability organ’ view might seem a bit protracted and unnecessary. However, it highlights why thinking in terms of *state* is useful for the engineering profession. Rather than isolated, separate and disconnected chains of technical activity, the notion of *state* gives a central, singular focus of responsibility and purpose for the upkeep and delivery of an intrinsic power (a ‘capability organ’) that can be immediately used by an end-user. It represents the inherent role engineers play in the delivery of capability – whether a force element to fight in a war, the capacity to move people and freight according to a schedule (like an airline), or for a stocktrader to engage in their business (with the requisite IT infrastructure ready and working).

Contrived preferred-state (via technological elements) means having a potent, active and functional presence that can be readily, and immediately, be transformed into a power to create an effect. Much like an enzyme or biological culture can be inserted into an ecosystem and, by nature of its interaction, creates an effect, so too is this view of engineering.

26.5 Examples of ‘contrived preferred-state’

Much of this discussion has been theoretical thus far. How does the notion of engineers as contrivers of a preferred state look in the real world? This question is explored through some generic examples.

26.5.1 Bridge infrastructure

Consider all-important bridging infrastructure across the world. Bridges can ‘better’ a city’s transportation system by connecting parts of a city in a way that benefits large numbers of people that would previously be relatively more inconvenienced.

Civil engineers are the key ‘contrivers’ of this betterment in many ways. They work hard to ensure the bridge is sturdy, aesthetically pleasing, that the design is mindful of the local environment, has useful features to ensure traffic monitoring and flow, and presents a safe transport corridor. These facets are not just design factors identified at the start of the effort to make a bridge possible; nor are they a snapshot of requirements fed into the design synthesis process that ‘churns out’ a suitable bridge design. After the action of bridge designing is complete, engineers continue to be engaged in the process of realising that bridge into the physical form, ensuring that those design features, based on original intentions, are fully implemented.

Following construction, engineers are still engaged in the presence of the bridge. Engineers then become involved in the important responsibility of ensuring that the continued functionality of the bridge – the ‘bettered situation’ – persists, through ongoing safety checks, the embodiment of upgrades, and perhaps the redesign of traffic flows to enhance capacity.

Thus, it’s important to note this important distinction: that professional engineers involved in the continued presence of the bridge are not all concerned with *building* a thing; however, all such engineers are certainly being all involved in *ensuring* something.

26.5.2 Telecommunications network

When considering a mobile cellular network, its 'benefit' has become such a given, many in society only notice its 'presence' when it suddenly becomes unavailable to use. The ability to make phone calls, send emails, or stream music almost anywhere is a highly valued capability.

For engineers, their responsibility for the upkeep of such a network presence is not merely in the design and installation of towers, data trunklines, or data centres. Obviously, the infrastructure needed to deliver a network experience is crucial; however, ensuring proper maintenance and defending against any factor that could cause the system to lose capacity, or shut down altogether, is also a vital pursuit of professional engineers. Whilst much of the physical checking and intervention on the infrastructure is done by technicians following maintenance instructions, professional engineers still retain a vital role in lending a cognitive edge to this pursuit – identifying, analysing and preventing factors that affect system availability. Whilst they're not the 'hands and feet,' professional engineers are lynchpins in contriving a state of availability, and a sense of instant connectivity, for network users.

26.5.3 Software

Software is an interesting case, given there is no 'physical construction,' aside from the 'physical' upload of software onto a hardware device that operates it. Software engineering isn't so much concerned with rearranging physical 'stuff' as it is concerned with the intentional transformation of data and information for the benefit of defined users.

The software that engineers 'build' helps unlock the processing abilities of a device for the benefit of a user. Once again, however, engineers are present throughout the whole experience of a user interacting with that software. Aside from seeking a host of information-processing functionalities, engineers are also involved with other facets, including 'bug' isolation and solving, solving hardware processing issues (software/hardware integration), cyber-security factors, as well as examining improvement opportunities for the software. These are beyond development activities and instead are directed to ensuring the ongoing, accurate delivery of intended benefits to the user. They are concerned at all stages of the software development cycle with the condition that software presents to stakeholders.

26.5.4 Environmental engineering

Perhaps a whole discipline that illustrates more clearly the notion of contrived preferred-state is that of environmental engineering. Environmental engineers engage in a wide variety of activities; so, for simplicity, the example of flood prediction and modelling will be considered.

In this instance, environmental engineers seek to understand how a particular region may be affected by excessive rainfall where catchments are inundated, and excessive amounts of water flow into local communities. Such engineers can then use that understanding to undertake a series of interventions to minimise the risk of such a flooding event – whether new or upgraded infrastructure, development of evacuation plans with government agencies, or flooding rescue plans with emergency service providers. There may not even be infrastructure works; the process of boosting and ensuring community readiness and resilience might be sufficient to be a contrived preferred-state for that region.

While environmental engineers do often operate as a 'contributor' rather than as an 'instigator' of an engineering pursuit, they may also be involved in development works. Nonetheless, such engineering activity is directed to bringing into existence, and continuing that existence, a preferred state for an environmental context.

26.5.5 A much broader profession

Whilst these contextual examples highlight the contrived preferred state approach, it's also instructive to consider other means, or as will be explored shortly, other *modes* of engineering:

- **Technical regulatory authorities** are focused on the state of a fleet, or a broader system or product – inherent characteristics that might affect the safety of operators and the general public.
- **Engineering consultants and advisors**, whilst not engaged in the *designing* process, still contribute critical information and authoritative advice. They help manage state, for instance, by introducing decision certainty (via modelling) or determining fit-for-use status (raising the achievability of an engineering project).
- **In-service operations and/or support engineers** are engaged in ensuring that the system or product that is in use continues to replicate the original intended characteristics and functionality faithfully, and where it doesn't, that corrective actions are implemented. Also, where the operator needs different characteristics or functionality, such engineers are the ones that coordinate and deliver such state changes.
- **Business development/sales engineers** are technical professionals who use their engineering nous to help realise and implement a state change in the realm of a customer organisation. They're not likely to be engaged in system design, but are highly attuned to understanding the customer's needs, and matching an engineered solution to meet those needs. To use this chapter's vocabulary, they help architecture the contrived preferred state for a customer.

From these few examples, it becomes clear that engineers work in various ways and in various team structures to contribute to the goal of a contrived preferred state. Not only does each discipline of engineering have something to the bring to the technical tasks at hand, each style of engineer – each *mode* of engineering – plays its part in the bigger story.

26.6 Engineering's fifth manifestation

26.6.1 A mode

One of the central contentions of this chapter is that contriving a preferred state is engineering's core modus operandi. However, the engineering profession doesn't just operate along technical or specialist disciplines, but this study contends they also engineers work in many different types of *modes*, all orientated towards a preferred state.

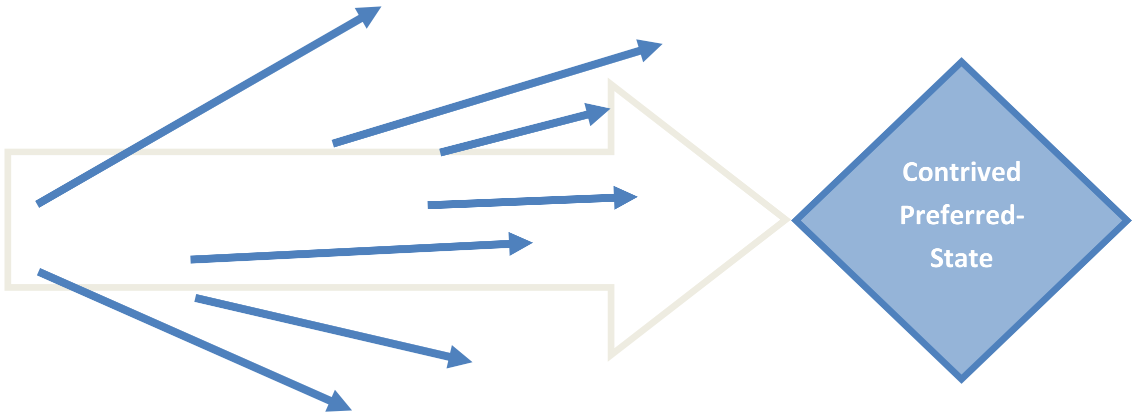

Figure 89: The sum activity of all the various modes of engineering should be directed towards the contrived preferred state

26.6.2 Not just different disciplines, but different modes

A mode reflects a distinctive kind, or pattern, of work that reflects the nuances, constraints, imperatives and objectives of that modal endeavour. A mechanical engineer may work in a variety of different modes, whilst still operating from a similar knowledge base. However, the way in which that knowledge is deployed, the way that work activity is managed, and the purpose for which that engineering activity is directed can vary significantly (as seen in the previous examples). It also reflects the type of challenge or problem space the engineer (or engineering team) is seeking to solve – all aimed towards that big-picture of a preferred-state.

Mode can refer to a discrete task, through to an activity, through to a full vocation. At the more personal level for engineers, this is the manner with which they express their technical expertise and how they spend most of their professional time. Some engineers might be 'multi-modal,' whilst others might be singular in mode.

So what are some other examples of 'engineering mode'? Consider this non-exhaustive list of different modes of engineering:

- Project management
- Modelling and analysis
- Business development & sales
- Development and design
- System architecting
- Test & validation
- Manufacturing
- Regulatory oversight
- Research & development
- Niche specialty consulting
- Estimation
- Investigation
- Sustainment

- Operations support.

Whilst many of these modes are readily recognisable to an engineering community, they are perhaps not instinctive as each being legitimate and equal expressions of engineering, especially when driven by product-centric thought.

For the sake of simplicity, this study will simplify these various modes into the three more readily recognised forms of engineering:

- **Development:** Includes product development, designing, research, drafting, and layout.
- **Manufacturing:** Production or implementation of an engineering concept, realised into the real world.
- **Operations:** Includes in-service, sustainment, operational and asset management activities.

26.7 Is it that big a deal?

What does all this mean for the professional engineering practitioner on a day-to-day basis? Perhaps, in all day-to-day reality, it doesn't mean a great deal at all. Furthermore, even it becomes relevant for the engineer in the cognitive trenches, is it even an accurate thought system to be adopting?

26.7.1 New definition, same tradecraft

It may not seem like a big deal for many engineers because their existing work might already be highly congruent to them, especially those whose work is aligned to traditionally accepted definitions steeped in product-centric thought. However, this new CPS approach certainly doesn't devalue or dismiss this traditional approach and is still largely congruent with it. While this new definition schema seeks to reframe engineering in a more encompassing manner, the classical product-centric definitions of engineering can still be readily identified. Not only can it be identified, but it also illustrates how engineers' tradecraft is enacted – namely, as a cognitive undertaking.

In the design and development mode of engineering, engineers have at their disposal a range tools and cognitive approaches to fulfil their craft. In the cognitive domain, they understand the problem space they are tasked to address and test potential solutions using various analysis and modelling techniques. When they converge towards a design solution, they begin to 're-emerge' from this cognitive domain by providing designs – drawings and other communicated sets of information – that can be used to construct (arrange and transform the world around them) in a physical or literal manner.

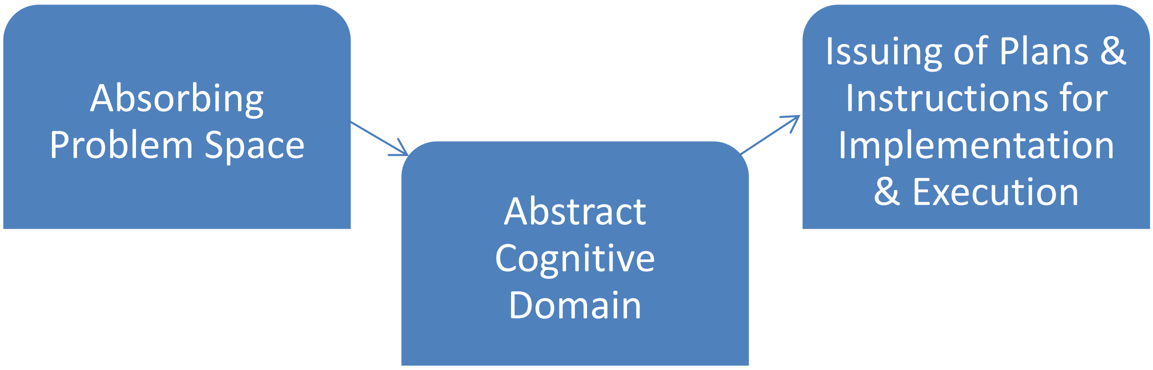

Figure 90: Engineering as a cognitive pursuit. Engineers assimilate the problem space into the cognitive domain where they analyse and eventually devise a specific intervention or system which must be transmitted out of the cognitive domain in a way that can be implemented in the real world.

Tradespeople can use this information to faithfully replicate into the physical world the artifice the professional engineers have conceived in their mind. Engineers monitor the testing of the physical specimen to validate their cognitive efforts. Upon validation, these designs are then put into 'production' – a more efficient means of bringing that cognitive work into the physical world.

26.7.2 Caveats & potential limitations of the definition suite

Understanding the caveats on this CPS definition suite is important before looking to adopt or reject it.

Some of the more pertinent caveats are that these definitions describe the essence of the engineering *profession*, rather than the duties and activities of individual engineers. When all the engineering efforts of engineers are pooled together, this is the effect that's achieved.

Furthermore, there are some fairly significant dimensions to the engineering profession and its associated disciplines that have not been formally taken into account when creating these definitions, although they have certainly been considered and reviewed whilst deliberating the question of engineering essence.

26.7.2.1 Engineering's cognitive approach

Because the CPS definitions focus on the bigger philosophical picture, they don't provide great granularity on the detailed cognitive process that is common to all professional engineers. They also don't offer much detailed coverage or description of the tools, methods, process or frameworks used in engineering pursuits, nor has much consideration been paid to the important contribution bodies of scientific and technological knowledge play (unlike the erudite contribution of Vicenti on the topic of engineering knowledge). Whereas other definitions focus in on the techniques and tradecraft used by engineers, this definition set is focused primarily at the meta-level, looking at the broader endeavour and effect of engineering.

26.7.2.2 Professional standards & expectations

This study has not formally looked in detail at the myriad of professional standards frameworks that professional associations often place upon their practising members. These frameworks represent the expected behaviours, traits, and considerations for decision making and personal conduct in a professional engineering role. These standards are underpinned by requirements often placed on education providers that form the curriculum for accepted engineering competence. Such standards reflect minimum demonstrated knowledge standards before one is admitted to the engineering fraternity.

Connected to the realm of professional standards is discussion around personal traits of engineers. These include characteristics such as creativity, curiosity, attention-to-detail, communication skills, and capacities to work in a team. Again, this field of discussion was not formally reviewed.

Also at the core of these professional standards are benchmarks between professional activity and mere 'tinkering.' One question to be asked is at what level does this 'contriving' activity constitute professional activity versus an amateur activity?

As such, a more systematic review of these standards and individual characteristics in light of the contrived-preferred state view of engineering may be illuminating.

26.7.2.3 Ethics & professional practice

Closely linked to professional standards is the active realm of engineering ethics. Here, questions regarding the professional conduct and decision-making of professional engineers are deliberated, studied and institutionalised. As engineering endeavours can involve potentially hazardous situations, emphasis is often placed on ensuring safety and quality in engineering activities, ensuring decisions are taken with due care. Engineering ethics also reflects a 'social contract' with the communities and society it operates in.

In addition to safety considerations, engineering ethics is also concerned with ensuring appropriate outcomes balanced against economic and political interests. Even where human life is not at stake, economic and political interests may still sway engineering judgement in a way that prejudices or disadvantages a community or stakeholder group. There are also more contemporary ethical challenges such as privacy versus sharing of user data.

Despite this extensive field, engineering ethics was only reviewed in a very general sense. The CPS definitions could be enhanced by a more thorough study of engineering ethics, especially with regard to 'active and latent stakeholders.'

26.7.2.4 Other considerations

There are other questions that could have been considered at a deeper level too, including:

- Who actually decides what the ‘preferred state’ is? Whilst it’s often a customer, there are often other stakeholders who weigh in on this definition in each case, including regulators as well as political voices. Arriving at a final definition for just what constitutes ‘preferred’ is going to be driven in some part by engineering ethics thought.
- Do these definitions truly hold for all engineering activity?
- Could there be a more thorough definition around what an ‘engineering mode’ is? In the view of this study, there’s scope to tighten this concept further.

26.7.3 Take a closer look

It’s these questions, plus an incomplete approach, that does lead to the biggest caveat: these definitions need further study. As a thought experiment, and as a set of working definitions for this study, they fit a purpose. Also, they’re certainly not definitions formed in a vacuum or without considerable thought and consideration. However, this is not the study to fully exonerate (or exterminate) these ideas. Such questions should be subject to more thorough and rigorous approach, something which might make for a stronger and more encompassing reconceptualisation of the engineering profession.

26.8 The bottom line

This chapter has been a deeply theoretical, conceptual and philosophical assessment of the nature of engineering, seeking to answer what is the essence and character of engineering. It has sought to ‘step up’ the philosophical understanding of engineering – the clear expression of how engineers create value for broader society – to a more comprehensive and more encompassing level. At its heart, it's placed greater focus on engineering’s role in how something is experienced in a social construct, rather than how it’s assembled.

26.8.1 From designing products to changing circumstances

Traditionally, engineering has generally focused on the physical definition of a product – the layout of a vehicle, the functionality of a system, or the performance of an asset. However, the notion presented in this chapter where engineers are truly concerned with *condition* or *state* presents a more comprehensive expression of what engineers really do. Ultimately, engineers ‘build’ functionality and end-user power that’s predictable, reliable and versatile.

Without question, products, systems, assets, or code are the main *conduits* to achieving a preferred condition. However, articulating what engineering is truly concerned with, in a way that is independent of the specific, physical concepts of product or designing, helps elevate an understanding and validation that engineers are inherently engaged in far more endeavours that *product development*. Engineers engaged in other activities apart from designing are just as legitimately undertaking *engineering* as their designing counterparts.

Engineers, trained in the engineering disciplines, possess a set of skills, techniques, tools and experiences that can be deployed in many diverse ways or modes, with this important caveat: each of these modes sees engineers using their minds, not their hands. The cognitive efforts of engineers are directed towards the end goal of a preferred-state, with engineers the key contrivers of this preferred-state. In this study's opinion, this is the true nature of engineering's core modus operandi.

26.8.2 Engineering in the Solutions space: a legitimate mode

Whilst redefining engineering can be intellectually stimulating, this study spends a lot of time on the matter for one reason: product-centric thinking about engineering devalues other forms and expressions of engineering, including operationally-focused activities found in the in-service, Solutions-focused environment. A new definition was needed to make all forms of engineering (including sustainment and in-service) more congruent.

This is also aided by conveying that engineering is expressed in many modes. It means that engineers engaged in the in-service environment do not have to be engaged in 'heavy calculations, detailed modelling, or layout drafting' to be engaged in the activity of engineering legitimately. The CPS definition removes any class distinction from 'real engineers' versus 'paperwork engineers' (or other demeaning titles potentially assigned to non-designing engineers).

This helps free up the mind to examine some of the nuances, nature, and imperatives of professional engineering undertaken in the in-service environment of a Complex Integrated Solution. This rationale of contrived preferred state is used to better understand the role of engineering in the Solutions environment, particularly the in-service aspect. It's explored in more detail in the following chapters.

CHAPTER 27

Revisiting Airworthiness Management

Recasting a Critical Responsibility

27.0 Finding a new lens for airworthiness management

This section turns again to the realm of airworthiness, this time to present a new system of thought and set of conceptualisations (or re-conceptualisations) about the field of *airworthiness*, and in particular, *continuing airworthiness*.

27.0.1 An existing practise

But why? What's deficient about the existing knowledge and understanding of airworthiness? In practise, perhaps not much, as there exist many strict regimens around the management and control of airworthiness. However, consider that modern airworthiness management:

- Is more a practise demanded by strict process, rather than a clear discipline (what's *done* rather than what's *taught* and *developed*),
- Has emerged from years of practise (including learning from negative events), rather than built up from first principles, and
- Places a priority on *compliance* rather than *understanding*.

Even the encyclopaedic yet concise book by De Florio on airworthiness [230], whilst a practical 'plain-English' guide to airworthiness concepts, does use a traditional regulatory-driven view of the field. 'Bringing to life' the nature of airworthiness, and the subtle nuances of how to manage it seems to be lost on most published airworthiness works [231][1].

More relevant to this study, though, is that to construct a more cogent management methodology for the Embedded Engineering Function archetype, the area of airworthiness management must be explored with fresh perspective.

[1] Works by Swift are a standout of putting a different light on the topic

27.0.2 A new perspective

Thus, this chapter seeks to swiftly make a somewhat unorthodox, first-principles contribution to airworthiness management, laying down nine key tenets from which other airworthiness management activities stem. These nine tenets can definitely be accompanied by other more traditional concepts or principles, such as the need for strict configuration control or the practise of Instructions for Continuing Airworthiness. It could also do with greater expansion and development. However, this chapter's contributions are mind prompts and analogies to help garner a firmer grasp on the sometimes nebulous concept of airworthiness – a subject that can be difficult to visualise.

27.0.3 A practical starting point

As an important starting point, airworthiness" is practically viewed from three perspectives:

- **Type:** The original blueprint of the type of aircraft – made-up of fleets, and individual aircraft, all around the globe.
- **Fleet:** Some collection of the same type (even model) of aircraft assigned to a particular operator group. This may just be for the overall type (e.g., Boeing 737-800), but often may be viewed with more granularity at the sub-model level (B737-832 – a slightly different aircraft to other -800 series aircraft, with minor differences in features, equipment or layout).
- **Individual 'tail-numbers':** each distinct, separate, individual aircraft (each separate serialised airframe).

In addition, it's important to note that whilst these tenets keep all airworthiness stakeholders in mind, they're particularly conveyed through the prism of the Embedded Engineering Function.

27.1 Tenet #1: Airworthiness is about confidence

As seen in Chapter 11, of the few key definitions of airworthiness, the key elements are:

- The fitness and condition of an aircraft
- Operating without hazard to immediate participants (crew & passengers) and third parties (generally on the ground) in the envelope the aircraft is expected to encounter.

These are highly indisputable characteristics of the term. However, this study would add one extra element to it: The confidence to fly the aircraft, and for it to behave as expected.

This emerges for two reasons. One, it's of the same logical vein of the definition of safety in Chapter 11 where 'safety' is more about assurance and confidence, rather than the absence of harm. Two, because one can never be 100% certain that an aircraft is airworthy – so when various stakeholders declare an aircraft 'airworthy', it's a reflection of the confidence they have in the aircraft based on what they know, rather than an absolute knowledge.

As such, this study defines *airworthiness* as:

The contrived state of the aircraft where there is a prolonged confidence in the aircraft's ability to behave as expected and fly at or below a socially accepted probability of harm to aviation participants and third parties.

27.2 Tenet #2: Airworthiness is ultimately something manifested, not just declared

Airworthiness is determined and declared by humans – a justified belief that an aircraft is in a state that it is fit to fly according to a social code (i.e., the certification standard that reflects the expectations of society). It's a determination that's made on an ongoing basis when aircraft are permitted to fly via the maintenance/service release process – not just at a decision gate like certification.

There are plenty of procedural mechanisms that help professionals with responsibility for airworthiness make that determination on a frequent basis (e.g., MR/CRS), but ultimately it's after humans (engineers) have made a judgement call, and this is a cognitive process.

As such, one of the real ironies of airworthiness management is that aircraft can be signed out via maintenance release as 'safe' from a legal and procedural standpoint, and still have a latent issue that makes it ultimately u*nairworthy*. That latent issue may not manifest at all during a flight; sometimes it starts to reveal its physics of failure (the measurable, observable and physical degradation towards a failure condition). Sometimes, it conceals itself until it's too late.

Those latent issues could be an array of matters – from maintenance errors, to undetected faults, to something more of a design flaw. So, what are all these processes of certification (of design or maintenance) really about? They are declarations of airworthiness.

Ultimately, however, airworthiness is something that is manifested, not just declared. It is an attribute of that system's behaviour – a displayed characteristic. In the same logic as safety is a positive outcome, and not merely the absence of a negative one, so too is airworthiness – it is something that is manifested.

27.3 Tenet #3: Airworthiness is more than hardware safety

Airworthiness is more than minimising the probability of a catastrophic failure of the aircraft system (airframe or systems) due to system design factors or manufacturing/maintenance quality – although, this is a critical focus.

It applies to 'non-physical' aspects as well. Consider the following:

- Airworthy doesn't always mean 'defect free' – aircraft are permitted to fly with certain carried-forward defects. Even some unapproved defects would not pose a danger from a catastrophic failure perspective. However, could those defects introduce greater workload or be a source of confusion for the crew, potentially leading to unsafe errors?

- Are there sufficient instructions and checks to find issues?
- Are the performance charts in the flight manual sufficient and accurate to ensure safe manoeuvring?
- Has there been suitable physical control over the aircraft so that there is no damage, change or interference to the aircraft's configuration – whether by error, by the environment, or by nefarious acts?

Figure 91 presents five key elements to where an aircraft might be deemed 'airworthy' – the five factors that would cause someone to have a prolonged confidence in the aircraft before they flew in it. Those five areas are:

- **Robustness and integrity of system design:** the validated and qualified design of the aircraft.
- **Integrity of physical and software build:** the physical completeness and quality of aircraft's physical construction (including software 'build') – both after initial production and after maintenance.
- **Comprehensiveness of inspections/system of detection of unsafe conditions:** the ability to gather sufficient knowledge about the state of airworthiness of an individual aircraft, via maintenance inspections, captured system data (e.g., health prognostics) and other reporting systems.
- **Qualified execution envelope:** This is the 'performance zone' of how the aircraft is operated and includes performance limitations/bounds, procedures/sequences, and other safety-sensitive actions when using the aircraft. Having confidence in this qualified execution envelope is essential before it is safe to go flying.
- **Controlled interactions, interfaces and interventions:** This goes to the next tenet on the 'sphere of safety' and is in addition to the integrity of the aircraft build. This facet is an assurance about access to changing the aircraft, whether it's by maintenance crews or non-human interventions such as environmental conditions. There is also a security element – confidence that the aircraft has not been sabotaged or altered, whether by physical interference or by some other means (a cyber-related alteration to the operational flight software, for instance).

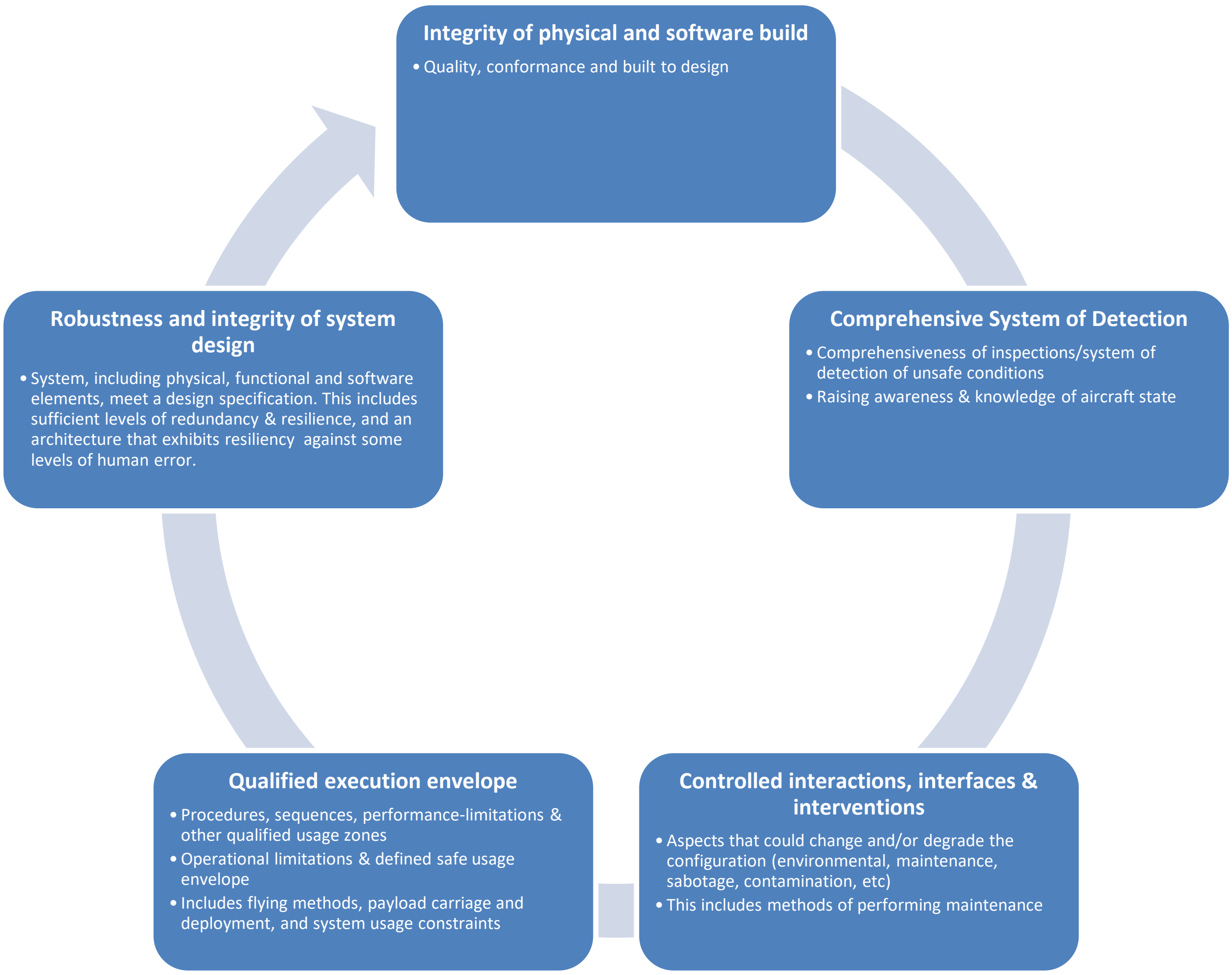

Figure 91: The five key management elements for an airworthy aircraft

27.4 Tenet #4: Airworthiness management is patrolling & controlling the sphere of safety

Imagine a scene from the TV series 'Under the Dome' – a transparent, but impenetrable sphere that isolates the town from the outside world.

The 'sphere of safety' can be conceptualised as a transparent dome that shields an aircraft – a visible (but transparent) 'bubble', denoting that although a broader environment surrounds the aircraft, there is a protective force that delineates this broader environment from a protected and controlled space.

Figure 92: A visualisation of the ‘sphere of safety’

Those engaged in airworthiness management, especially continuing airworthiness management, are engaged in the business of defining, patrolling and controlling this sphere of safety around each aircraft. Enforced in this sphere of safety are:

- Highly controlled activity and interactions with the aircraft – only authorised persons can perform authorised tasks with authorised tools, and only fit authorised and controlled parts.
- A high degree of awareness and knowledge of what goes on in this protective sphere. This includes matters regarding the aircraft’s technical state, its operation and use, as well as the maintenance environment.
- An active defence to keep threats isolated from this pristine environment, such as unapproved parts, maintenance errors, unapproved instructions and actions that may jeopardise the integrity of this sphere of safety.

This sphere of safety is something a number of airworthiness practitioners seek to uphold, including personnel in maintenance organisations, flight operations groups, or engineering/continuing airworthiness management groups. However, it’s generally the EEF who are ultimately responsible for its definition and overall control of this sphere, as it is they who are ultimately responsible for presenting a qualified, safe capability to an operator for their use.

It’s this controlling of this sphere that permits professional engineers to undertake their practise of contriving a preferred state. This is generally done through the five key airworthiness elements described previously.

27.5 Tenet #5: Airworthiness management is a common goal, with different responsibilities

Where *airworthiness* pertains to a confidence in the state of an asset's existence, this study asserts that *airworthiness management* is:

> the full spectrum of intellectual, procedural and physical efforts to determine, corroborate, understand, assess, correct, and instil that confidence on an abiding basis.

Airworthiness management is a spectrum of activities enacted by various stakeholders – operators (via the professional engineering unit/continuing airworthiness management groups), maintenance providers, flight-operations units, manufacturers, and airworthiness authorities. For each stakeholder, 'airworthiness management' can be taken to mean something slightly different:

- For a continuing airworthiness management group, it is concerned with managing the ongoing status of a fleet of aircraft, ensuring compliance with mandated maintenance requirements, as well as monitoring (and intervening where required/permitted) local fleet health.
- For a Type Certificate holder, this can mean understanding the inherent safety of the product design, monitoring events with the aircraft used across the world, and issuing information and approved actions to correct unsafe conditions.
- For an airworthiness authority, it can mean oversighting the holder of a Type Certificate to ensure they're undertaking sufficient investigations into key issues affecting product safety, as well as to ensure the ongoing validity of the Type Certificate.

This spectrum of airworthiness activities is broken down into certification and continuing/continued airworthiness. Traditionally, certification has been the intensive field of responsibility – and point of achievement – of airworthiness authorities and manufacturers in ensuring a product meets a clear standard, proven by tests and analysis. In a similar vein, continuing airworthiness is not strictly a corporate function, nor a professional discipline – rather, it's a field of responsibility shared by several organisational units and stakeholders. It's intended to reflect an 'in-service phase' view of airworthiness management, calling up a series of operationally related activities.

However, this study seeks to point out this is perhaps not a thoroughly complete view of understanding the various aspects of airworthiness management.

27.6 Tenet #6: Airworthiness is managed in stratified segments

Aircraft certification is the bedrock of airworthiness. However, an approved design and produced aircraft are only the beginning of the dynamic world of managing airworthiness.

This study asserts that airworthiness is managed in various segments. However, whereas the language of 'certification' and 'continuing airworthiness' can imply these segments are sequential, this study asserts they are stratified levels – one building on top of the other to result in an airworthiness outcome. These levels of segments are Designed and Enacted, with a Manifested outcome.

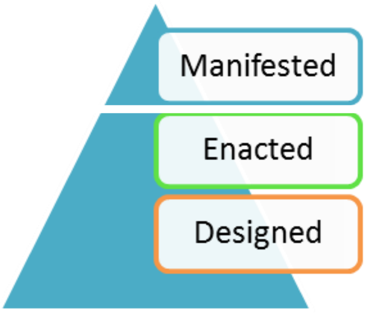

Figure 93: The stratified foundations and segments of airworthiness management

These levels don't immediately map to the certification/continuing airworthiness paradigm – these are fields of responsibility, rather than segments to be managed. The realm of continuing airworthiness does actually come back to the Designed level in some aspects, as will be highlighted shortly.

27.6.1 Designed

The Designed level is the realm where more of the traditional design certification activity is performed – where what's intended is defined, specified, designed, and subsequently certified. Certification is a 'graduation-point' – proof that the design or artefact has indeed complied with a defined standard. That standard may well be hard-won, in many instances, paid in blood. However, declaring compliance with a standard does not alone make it 'safe.'

This Designed Domain also includes the requirements imposed on the Enacted domain, such as the maintenance instructions and schedules, as well as operating data.

As this model is based on sequential conceptual levels – and not sequential tasks – it follows that the Designed level of airworthiness management can be revisited during the aircraft's life. Changes, corrections and improvements to this level of the airworthiness management stack ensure a correct foundation can continue to be relied upon. This is generally driven from a continuing airworthiness realm of responsibility

27.6.2 Enacted

Enacted airworthiness management is the domain of aircraft production as well as of maintenance. Both are activities that implement and ensure a configuration that replicates the aircraft design. If the product has been determined to conform, or if inspections and repairs are carried out correctly, it is signed off – and thus declared – as releasable to service.

27.6.3 Manifested

This is the airworthiness as an *outcome,* rather than a manageable segment.

As discussed before, airworthiness is ultimately something that is manifested, and not just declared – it is an inherent attribute the aircraft reveals and demonstrates when flying. The aircraft behaving as expected in a reliable, consistent manner is how airworthiness is truly manifested – and if issues are not caught and managed at the Enacted level, it will manifest operationally.

The act of managing airworthiness at the Manifested level is ultimately one of observation and monitoring – a key facet of the *continuing airworthiness* responsibility.

27.7 Tenet #7: 'Continued airworthiness' is about instantaneous confidence

If one looks at an aircraft parked at the gate, how do they *know* that it is *airworthy*? How do they have confidence, as an operator or aviation participant, that the aircraft will, most likely, not cause harm? This is the domain of Continuing Airworthiness.

As such, this study defines the field of *continuing airworthiness* as being:

> concerned with strategies that help stakeholders have confidence in the instantaneous state of safety and integrity of the aircraft.

It's a field that could potentially be viewed as the 'poor cousin' to certification – confined to preserving a pre-existing state of airworthiness declared at certification. Whilst this is not an untrue responsibility, the continuing airworthiness responsibility calls for a style of work that is agile, dynamic and perhaps even enigmatic at times.

Many aspects of the continuing airworthiness responsibility are concerned with ensuring the necessary actions implemented in the Enacted domain are actually carried out, on-time, and to requirement – i.e., has maintenance been done right. However, there is a significant amount of intellectual work that must be performed in monitoring airworthiness at the Manifested level, and where required, then directing others to step in and resolve issues, either at the Enacted level or the Designed level. It is both of these foci that enable groups responsible for continuing airworthiness to provide stakeholders with confidence in the instantaneous state of airworthiness of the aircraft, fleet, or type of aircraft.

The logic behind these strategies is contained in Tenet 9.

27.8 Tenet #8: Continuing airworthiness management groups require a questioning mental posture

These groups are of sound mind, while being paranoid.

A robust continuing airworthiness management group will exhibit traits highly synonymous with High-Reliability Organisations, as outlined in Chapter 11. This includes an almost schizophrenic mindset – accepting the tested & validated belief that the aircraft design is safe, but it also constantly questioning that validity. Its posture is to constantly be looking for evidence to the contrary, and rather than dismiss an anomaly as 'noise' or an outlier, it views such events with suspicion.

This trait is in support of a deeper drive to be constantly looking to enhance and fashion a more sophisticated mental model of the health of the aircraft under their jurisdiction. This reluctance to simplify is established on their belief that not all failure modes are known and accounted for, and that there is always new ways for things to potentially go wrong. This drive for a complex mental model is pursued from both an Enacted, as well as Designed level of airworthiness – that is, looking for new failure modes due to design, construction, or methods of maintaining the aircraft.

This mental posture is reflected in the Cognitive-Action Continuing Airworthiness Management Model.

27.9 Tenet #9: The continued airworthiness cognitive management model

Whilst airworthiness management demands physical interventions and the following of organisation procedures, the professional activity of managing and controlling airworthiness is substantially a noetic pursuit.

Figure 94 identifies key organisational processes of an operator-centric continuing airworthiness management/engineering group, with a reference to the intellectual efforts involved, particularly in identifying *systemic issues*. Known problems with a treatment need only be monitored for effectiveness, and are implementable by a maintenance organisation.

This management loop starts with experiences with the aircraft, both in-operation and in-maintenance, form part of a work program to monitor the health of a fleet which helps inform a cognitive picture – or mental model – of the fleet. If it's judged that there is an unsafe condition in the fleet, this issue then goes for deeper investigation to substantiate the level of the issue, with a view to creating corrective (and potentially preventive) actions.

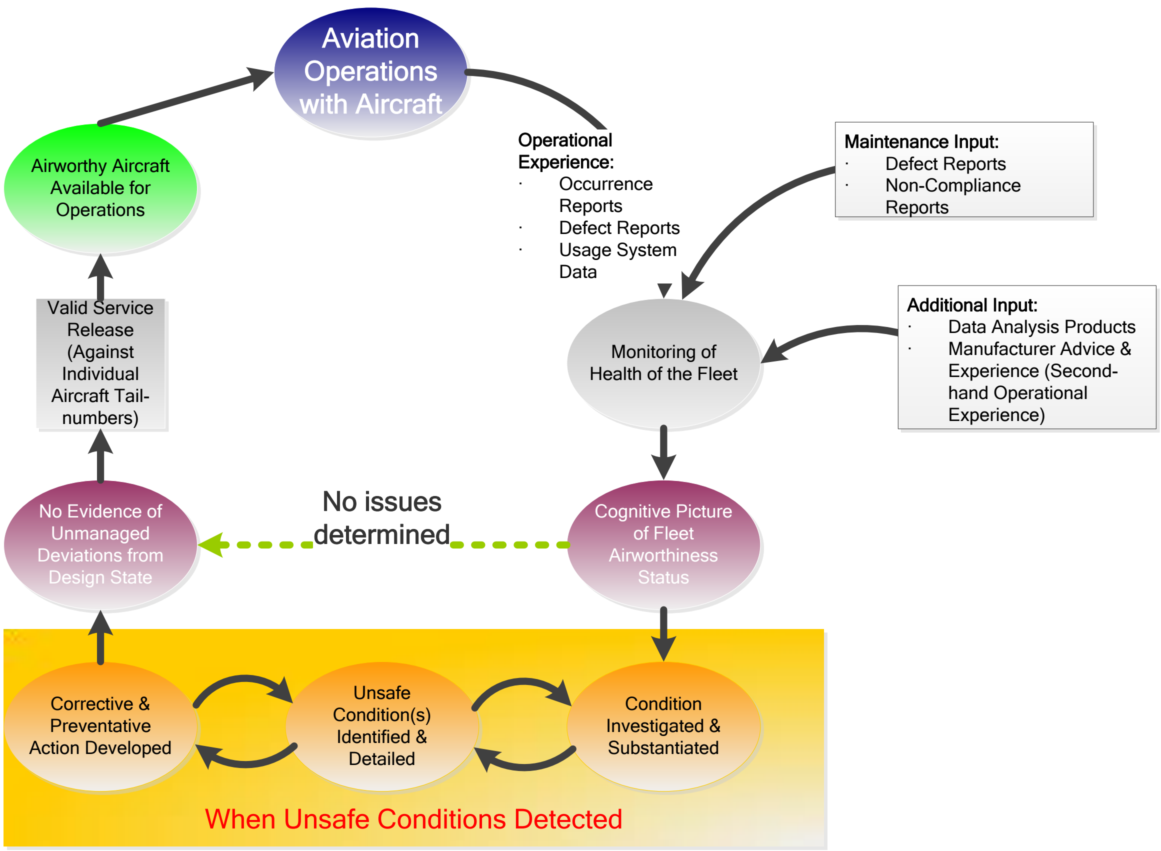

Figure 94: Continuing airworthiness management loop

27.9.1 Going deeper

However, what goes on in the mind of continuing airworthiness professionals – as individuals and teams, and in operator engineering groups, and aircraft manufacturers? To look at this closer, consider Figure 95 which breaks down aspects of Figure 94 into some more specific features.

It begins and ends with the aircraft's actual state – and the series of steps in the continuing airworthiness management loop. This loop can take minutes, or sometimes up to years.

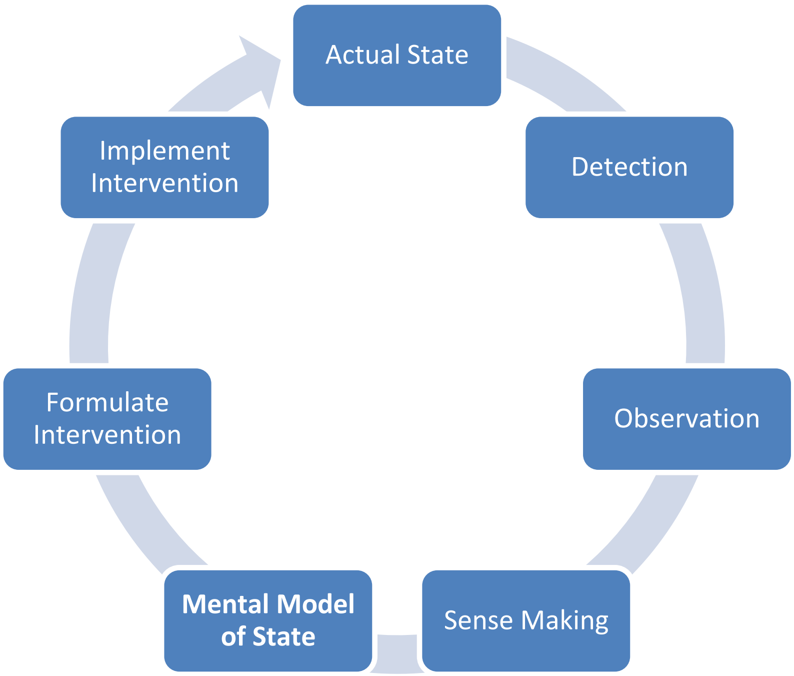

Figure 95: Continuing airworthiness cognitive management model

27.9.1.1 Actual state

This is the 'true' condition of the aircraft, whether in truly perfect health possessing no flaws in design, build, or qualified execution envelope – or whether there are hidden and latent issues lurking beneath the surface.

27.9.1.2 Detection

This involves techniques and strategies for identifying and capturing the 'health signals' that the aircraft emits, whether the first few steps of the 'physics of failure', or signs of robust design (e.g., things not failing when they're expecting to). It's the actual *activity* of detection, versus the information that is detected. Sources of such signals include:

- Maintenance actions to undercover and discover the true state of the health of an aircraft
- Modelling & prediction analytics, such as HUMS and other operational sensors to expedite and provide in close-to-real-time the same information (or indications to investigate further) gained from maintenance
- Defect and incident investigations
- Pilot/operational reports of issues.

27.9.1.3 Observation

Beyond detection (essentially data/information gathering) is the beginnings of the cognitive process of managing airworthiness. It is the registration and collation of this data/information – both procedurally/administratively (e.g., database and other records in a manageable way), as well as mentally.

27.9.1.4 Sensemaking

Here the airworthiness professional asks several questions to try and assemble these pieces of information into a more meaningful mental picture of the phenomena they've been able to detect and observe. Some of these questions include:

- How does this correlate to predicted reliability?
- How does this correlate with what was learnt during development or certification tests?
- How far away from a catastrophic event does this condition present?
- What could have happened?
- How likely is this part of a broader issue, or an isolated one?
- What is the likely explanation for this observation?
- What are other alternative explanations for this observation? How probable are they? How catastrophic might these alternative hypotheses be?
- Are existing defences/mitigations adequate?

27.9.1.5 Mental model of state

The results of this internal 'fact-checking' and assembling of observations lead to confirming, correcting and reshaping of the mental model of the aircraft's true state (whether for individual tail numbers, fleet, or type design). This mental model also reflects the beliefs held about the state of the aircraft. This is where the 'instantaneous confidence' is ultimately declared from.

Of important note is that a mental model is something that is held by an individual. It's difficult (if not impossible) for one individual to absorb all the available information available concerning an aircraft, and thus must rely on other summarised information sources, as well as other professionals, to form such a judgement. It's here that this model needs far more work to be an accurate representation of the sophisticated mental and interpersonal communicative processes that lead to an individual (such as a Chief Engineer, or a more detailed professional operative responsible for a particular area, such as avionics) to form this judgement. The fact that aircraft development programs involve thousands of people, no one person can truly understand how a modern, sophisticated aircraft entirely works.

This is a systemic field of verified trust. However, it does help visualise the various airworthiness management steps for a professional and helps shed light on the internal operations of the Embedded Engineering Function.

27.9.1.6 Formulate intervention

Of course, there will be instances where something doesn't add up which triggers further work to quantify a prospective issue. It might be a design flaw, a misinterpretation of operating instructions, a potential operating hazard that has been spotted, or some other facet of the aircraft's condition or state that might mean it's inherently less safe than assumed. In such cases, airworthiness professionals then turn to formulating interventions to redress that flawed condition. Typical interventions can include:

- Operational limitations

- New procedures
- System redesign
- More detailed inspections
- More frequent inspections to increase probability of detection.

27.9.1.7 Implement intervention

Once a course of action has been decided, it then must be issued as an authoritative instruction for implementation by those empowered to do so (such as maintenance, production, or flight operations).

However, that's not the end of the intervention; did it actually work? Does there need to be refinements made to the 'fix'? Did the solution fix the wrong factor? For example, what was thought to be an avionics issue affecting some flight control upsets turns out to be ice accretion on actuators that set of a chain of events that mimicked a flight computer problem. Thus, after an intervention has been implemented, the entire cognitive management model goes through yet another cycle to track the effectiveness of that intervention.

27.9.2 The result?

This cognitive model reflects that airworthiness management doesn't just follow a process – it reflects that airworthiness professionals need to be constantly 'on', vigilant and aware. They need to be constantly building and rebuilding their mental models concerning the aircraft they are responsible for – whether as an Embedded Engineering Function, as a Type Design Holder, or as another outfit with responsibilities for continuing airworthiness.

As has been pointed out, this model is not a fully cognitive and interpersonal communications map – such a construct would be a very sophisticated product that warrants a major research piece. However, this model does provide a general outline of the mental process that airworthiness professionals need to observe to discharge their responsibilities effectively.

27.10 So, what's the point?

The whole purpose of this study is to generate insights to help build a more cogent management methodology for sustainment-focused Complex Integrated Solutions. So how does this detour into airworthiness help?

Primarily because the Embedded Engineering Function's most critical responsibility is for airworthiness and safety. Mismanage this responsibility, and all the other facets of the EEF – and indeed, the whole Solution – pale into insignificance. While much of the airworthiness management spectrum, especially from a practical implementation perspective (e.g., maintenance), is quite established, the intellectual regime of managing airworthiness seems less settled. Understanding the noetic side to the airworthiness 'fight' is important, as this is the domain of professional engineers in this context.

Whilst there are numerous processes and clear airworthiness requirements and frameworks, these must be tempered and supported by an understanding of the 'unwritten rules of the game'. As such, to generate a clearer management approach for the EEF, and indeed for an entire Solution, understanding the nature of airworthiness, and being able to visualise how it can be managed is instructive in establishing a coherent CIS Embedded Engineering Function archetype[2].

[2] It may also be instructive for existing airworthiness practitioners in more conventional environments, too.

CHAPTER 28

The Solution Sentinel

Towards an Archetype of the Embedded Engineering Function in the Solutions Paradigm

28.0 Rethinking the Embedded Engineering Function

If conventional models for the Embedded Engineering Function don't entirely stack up in the Complex Integrated Solutions environment, then what is an archetype or some key principles that might help practitioners build a more suitable organisational unit?

This is the key question that this Chapter seeks to answer. In doing so, it gives a new perspective on the Embedded Engineering Function and fresh ideas for a more comprehensive management methodology for sustainment/fleet-focused Complex Integrated Solutions that extends another layer deeper.

This Chapter is built upon insights initially shared in Chapter 25 on the need for a transfiguration quest, particularly the scope of what this study refers to as the Embedded Engineering Function. However, it also introduces insights generated from Chapter 26 on finding a more holistic view of engineering, and from Chapter 27 on rethinking airworthiness.

Understanding how an outfit creates value, even when it's not immediately clear to other stakeholders, is arguably an important tenet of a strong management methodology. Thus, to bolster this pursuit, this Chapter seeks to recast in-service engineering from being a 'poor cousin' of new product development to the veritable champion working behind the scenes to keep an operator's core-business safe and effective.

28.0.1 An archetype, not a template

What follows are four key principles pointing to an archetype of an EEF that's "Solution-aligned." They're principles steeped in learnings from the case studies, and represent a new way of thinking about Embedded Engineering Functions.

What this chapter does not represent, however, is a readily implementable template or organisational model for an EEF. In other words, they're not models that can immediately be lifted straight from this study and put into practice in any organisation. By definition, each 'Solution' (whether as a contract or as an internal service agreement) is unique, and devising an organisational form that can be implemented in every organisation is misguided. Instead, these principles are designed to be used by leaders and professionals to help them rethink their own engineering operations and implement changes or organisational designs that are tailored to their context.

28.0.2 Beyond the Solution paradigm

Further, whilst this archetype is steeped in the insights presented in Part IV, the principles presented in this Chapter may prove useful in contexts beyond Complex Integrated Solutions. Any paradigm of an enhanced, service-driven, and often performance-based regime that's built around a customer imperative, such as a highly commercially aware CAMO, will find strong alignment with these principles.

28.0.3 What's in this archetype?

This Chapter poses five key principles that either articulate some of the notable characteristics of a Solution-aligned EEF or better explain in-service engineering in general. In particular, this archetype reflects an engineering function that:

- Is the epitome of engineering in an operational mode
- Is the core contriver of a fleet-state that benefits a customer
- Has an enhanced, Sentinel mission
- Doesn't have one singular focus, but operates across four simultaneous fronts
- Is multifaceted and exhibits five dominant traits as an outfit.

28.1 Principle 1: The EEF is the epitome of engineering in an operational mode

It goes without saying that Embedded Engineering Function is a prime example of engineering in an operational mode, using the concepts developed in Chapter 26. However, what does an 'operational' mode look like? What is the nature and defining characteristics of engineering in an operational sense? What does it 'feel' like?

To truly appreciate a Solution-aligned archetype of the Embedded Engineering Function, it's important to appreciate some of the nuances of the operational mode[3] in contrast to the two other identified major modes – development and production. The attributes presented in Table 11 explore these contrasts.

[3] It's also important to note that there are other entities engaged in similar expressions of engineering, such as the Type Design Group (and other Design Certificate Holders), although they are in what might be termed a *deep system support mode* as they are not directly engaged in the daily delivery of a fleet operations unlike an EEF. They're not considered in this Chapter.

Table 11: Nature of engineering modes

Aspect // Mode	Design Mode	Manufacturing Mode	Service/Operations Mode
Management Approach Main technique or model	Project focused	Implementation focused	Operations and service focused
Conceptual Management Model Core published management framework	Systems Engineering	Quality Management Systems	Service management/emerging
Operations Cycle Type of workstyle cycle	Work through a project lifecycle with significant decision and review gates.	Execute a program of repeatable work-package on a cyclical basis	A mixture of programmed activities (such as planned work campaigns) and unexpected arisings to be solved in a critical timeframe. Sometimes described as 'constant firefighting'
Variability How much deviation from a 'smooth, expected workstyle' (i.e., surprises) over a period, including an unpredictability of factors and conditions that must be satisfied.	Exists, but often in a latent manner. (eg, requirements creep, interface management).	Occasional-to-often. (When starting a line, more variations likely; a mature line is likely to be smoother with less out-of-the-ordinary surprises)	Significant and often fluid. (The day often cannot be planned; what is imposed one day may change to something else the next)
Sense The nature of the workstyle/ imperative imposed by the context	Divergent-to-Convergent	Determinant (the end-result is clear)	Reigning in a tendency for divergence
Achievement horizon Workstyle completion point ('the end')	A fairly fixed point in time in the future Proof that objectives met by the project organisation. A 'finite game.'	When product is released as complete (i.e., achieved a defined build-state). An 'infinite regimen of finite games.'	Unending (except for when a fleet is decommissioned). An 'infinite game.'
Measures of Success Rather than where a task is deemed 'complete'	Goals tend to be expressed by schedule aims, cost targets and system performance specification as determined by requirements	Goals generally expressed in terms of consistent quality, cycle time, and efficiency/productivity.	Goals are expressed as availability, reliability, safety and responsiveness, with a close eye on cost drivers.
Directional Sense of Exertion What the workstyle 'feels like'	Pushing forward	Pushing out	Pushing/holding up
Key Timeframe Measures Normal problem-solving turnarounds, or the measure of time used in planning	Months to years	Weeks to months (for a whole aircraft). Sometimes days.	From weeks, to days, to hours [For very front line support, minutes]

28.1.1 Nature of the pursuit

A leading distinction between a *developmental* and *production* mode, versus an *operational* mode (and to a lesser extent, a *support* mode) is that of the type of task to be performed. The operational mode of engineering finds itself enmeshed in a very dynamic environment that exhibits higher levels of uncertainty and where diverse challenges are persistent, both in an immediate sense, but also in the sense of 'looming behind the scenes.'

This is in contrast to other modes. Design engineering is quite singular in its focus: meet the specification, and finish the product. Whilst there are countless complexities in the huge quantity and variety of the challenges engineers face in this mode, there is generally a predefined point of success, with some model or form of product success that is aspired to (such as design targets). Whilst early in the design piece many options will be evaluated and exploration of the design challenge makes for many iterations, there's at least a point (even if potentially a bit fuzzy) where the result is clear.

In a full-rate production environment, engineers will still be encountering a variety of challenges – some routine, some potentially quite abnormal. It's perhaps a blend of the developmental and operational modes, with the difference being how anomalies can be contained. Whereas production can contain such anomalies benign environment (i.e., the factory), in the operational mode anomalies may be discovered when the aircraft is operational. Of course, anomalies found during maintenance are dealt with in a similar way to a production environment.

28.1.2 Approach to confining and controlling issues

Another aspect is the approach to controlling inherent problems that might emerge in aircraft.

In the development and production modes, a product is not released for use until it meets a set of criteria. However, in the operations environment, when an aircraft's service release is active, there is an assumption made that the aircraft 'is airworthy unless proven otherwise' (although the EEF will always be monitoring for evidence to the contrary).

Whereas the development and production modes can contain issues, uncertainties and questions in the design office or factory, the EEF has less of a luxury, with it having to live with the fact that aircraft might be flying with an issue whose nature is not fully quantified or managed. Whereas the development and production modes are 'offline,' engineering in the operational mode is like dealing with issues on a live patient. When they're experiencing issues, time matters to diagnose and find a solution. With aircraft in the sky while data is being analysed on the performance of the fleet, there is a tension between being suspicious of issues that emerge and considering the prospect that there actually is no issue.

This is not to suggest engineering units from the case studies permitted unsafe aircraft to fly; far from it. However, making a determination that something is genuinely unsafe can take time to verify, a process that is often done whilst aircraft are still flying. There exists a 'dual universe' where the aircraft is still believed to be safe; yet whose status is constantly being subjected to analysis. This leads almost to a 'split-personality' in the EEF's mindset (as outlined in Chapter 27) where it operates with an inbuilt risk management mental model: not be jumping to conclusions, whilst also remaining continually suspicious.

28.1.3 Timeframes

In a similar vein, timeframes are also a significant point of difference. Whereas design may take years, and production may take weeks or months, in the operational mode, engineering is dealing with *the now* (although it also has certain future foci, too). Its decisions or actions (or delayed actions) can see fleet unavailablities and operational disruptions that are immediately visible and perceptible by the customer. Again, this places pressure for fast decisions.

28.1.4 Sense of exertion

It’s also worthwhile considering how each of the different modes of engineering ‘feels’ like in terms of the directional sense of exertion; in other words, how efforts are mentally framed, and the nature of the cognitive burden of the task/responsibility.

This study puts forward that there is a different sense of exertion in each of the modes. *Development* is about pushing forward – working through the challenges, technical experimentation and iteration and overcoming technical impediments to devise a product or system that meets the original design goals. *Production* is about pushing out – working to find solutions to production errors or quality issues in a way that brings a manufactured item within an acceptable range of a product’s approved design, and push that item out and off the production line on-time and within budget.

An *operational* mode, on the other hand, sees its sense of exertion on a vertical plane, rather than a horizontal one: it’s constantly pushing or holding up. In this sense, there is a weight of issues that can strain an aircraft or fleet’s state below an acceptable level. Often its physical issues to do with the laws of entropy, where physical things simply degrade with time (whether in an expected or unexpected manner). However, other facets, too, seek to pull-down the future state of the fleet, such as obsolescence issues leading to supply issues, undiscovered failure modes, extra degradation effects due to environmental matters, or customer demands placing a strain on the fleet (whether physically, or on the Solution itself). As such, engineering’s key direction of exertion is on *up-keep*. This is one of the reasons this study views the term 'sustainment' as a more accurate reflection of the nature of the task.

28.1.5 Creative vs. administrative?

One aspect that hasn’t been caught up in the above framework is the nature of creativity. It can be easy to confuse the development mode as being highly creative, whilst the operations mode can be little more than administrative. In other words, while the development mode might be considered to be ‘real engineering’ (owing to its pursuit of innovative technical solutions that involve much creative genius), the operations mode is susceptible to a perception that it’s dull, is the bastion of clerical formality, and is devoid of creative pursuit.

Whilst record keeping and technical administration do form a key discipline of the operational mode, it’s important to point out that:

- It’s also an important discipline of any form of engineering, including developmental modes.

- Whilst it perhaps may be a little more pronounced[43] in the operational mode, it's not the only workstyle used.

Finding an exact breakdown of the levels of creativity versus other thinking styles isn't in the scope of this study. However, whilst creative product development may only be present in small quantities within an EEF (namely modification oversight), there are other important styles that play a vital role:

- **Problem solver:** often in a unique capacity for finding workarounds and dealing with fluid constraints (as opposed to more fixed constraints)
- **Guardianship:** possessing a constant vigilance and suspicion, always on the lookout for threats and issues that could cause an airworthiness hazard, pose a potential disruption to the customer's flying operation, or be a business risk to the Solution provider.
- **Director:** Whilst solving problems, the operational mode of engineering adopts a directive stance, much like a magistrate. This involves weighing up evidence and data before issuing directives that must be complied with.

28.1.6 Finding the right description

Trying to reduce down to one term or phrase that captures the essence of the operational mode of engineering – using terms more aligned with the human experience – is not straightforward. However, it might be best summed up using terminology from Chapter 26.

Ultimately, the term *contriver* is perhaps the best verb to describe the operational mode. Finding workarounds, plotting a way to keep the Solution in a steady state, and ensure the ongoing nature of the flying/operational tempo is at the heart of the EEF's role. However, it also has a guardian nature as well – it's the circuit breaker that halts any potential or actual unsafe condition, as well as guards against complex factors that could impinge on the customer's operations, and the Solution's business sustainability.

28.2 Principle 2: The EEF is the contriver of preferred fleet state

Armed with a new outlook on engineering established in Chapter 26, what does it mean for the EEF to be 'contrivers of a preferred state' in the operational environment?

First, it's important to establish a sense of what that preferred capability state is in this context.

28.2.1 Contrived preferred-state in the operational environment

Considering the case studies, the NAAF and EmeraldJet had a keen stake in not just having aircraft physically on the flight-line, but available, ready and possessing inherent traits.

For the NAAF, these traits included:

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[43] There's no data in this study to support this observation one way or another

- Lethality & training realism
- Survivability/durability
- Inherent levels of safety and airworthiness
- Payload functionality
- Inherent reliability & availability characteristics
- Cost behaviours.

For EmeraldJet, the traits are a little different, but still echo those of the NAAF:

- Inherent levels of safety and airworthiness
- Reliable infrastructure to support an in-flight product (IFE, food service, seating arrangements, etc.)
- Inherent reliability & availability characteristics
- Cost behaviours
- Navigational and other technical capabilities to permit efficient routes.

Much of these sounds like inherent qualities identified and used by a design team as part of the systems engineering process for developing the aircraft, and indeed, this is a true statement. However, in this instance, these attributes are traits that are manifested and can be 'experienced' by those who are involved with the aircraft, rather than attributes imbued into the design during the development process. Naturally, the genesis of these attributes started with the design teams who developed the aircraft.

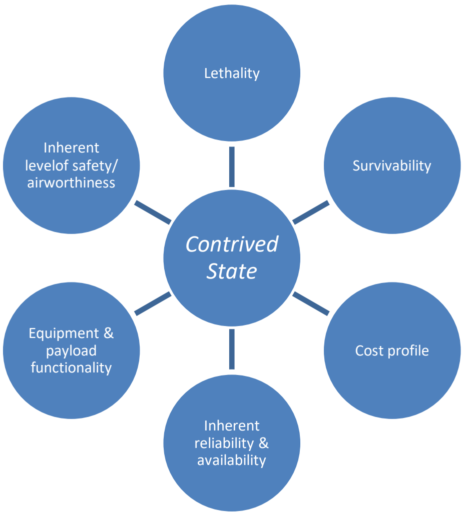

Figure 96: Aspects of a contrived preferred-state of a fleet of aircraft

So why is having an experiential view of these traits important, as opposed to a functional requirements view used to synthesise an aircraft design? Because it takes intelligent effort to see these characteristics be maintained and 'delivered' to a user on an ongoing basis. No product or system is imbued with 'eternal life' or such incredibly enduring features that it never needs human intervention to manifest these qualities throughout the life of a system, product, or engineered intervention.

In short, having a potential Capability – an organ of capability, as expressed in Chapter 26 – is the responsibility of the EEF.

28.2.2 How does EEF do it?

While 'contriving' has development connotations, it also has meaning that reflects planning, scheming and plotting. In this context, arranging and plotting to deliver a preferred capability state – an organ of Capability – to a customer end-user. This contriving is done on two levels:

- Maintaining the existing baseline of preferred capability state
- Working to enhance, grow or adapt this state to catch-up with stakeholders' view of what preferred actually is (i.e., those activities to do with development, improvement, and enhancement).

28.2.2.1 A capability-state

An important point must be made clear. It's engineers who monitor and intervene – that is, contrive – not just the state of the fleet of physical aircraft[44]. The EEF is engaged in ensuring the technical elements the operator needs to go flying safely. This means the EEF will be engaged in other facets too, including:

- Training and simulator equipment, along with data and algorithms (although another engineering authority might manage these, depending on the operator)
- Equipment and payloads for the aircraft to use in-flight
- Ground support equipment and support tooling
- Technical & operating data – the 'Qualified Execution Envelope,' as well as the Technical Management Policy that dictates the way the aircraft may be altered and repaired, and the comprehensive system of detection.

It's all these elements brought together and deployed in a 'clever' way that permits an operator to conduct missions and use. It is this whole 'system' that this study refers to as "capability state."

This "capability state" is deliberately a 'small c' term. Following on from the logic in Chapter 26, it is the domain of users who convert 'state' into Capability ('big-C') – the power to create effects. However, also following the convention of the logic put forth in Chapter 25, all the above elements are necessary to 'produce' (or contrive) a fleet of aircraft that present the user with the necessary abilities for it to be used in a mission. This 'system of systems' is referred to as one of the organs of Capability – one of the 'live' elements brought together by a user to generate Capability.

To reflect the contrived preferred state notion with that of an organ of Capability, this study simply refers to this holistic arrangement as a *capability state*.

28.2.2.2 Maintaining a baseline

Whilst 'maintaining' state sounds like being a staunch conventionalist or traditionalist, only seeking to maintain a fusty status quo, it's far from static – it's a very dynamic process, even if there may not seem to be a great deal of progress.

[44] Although monitoring the condition of the aircraft is definitely part of the course

And whilst the aircraft fleet may be imbued with intended characteristics, there are factors that may cause an operator to experience degraded levels of those qualities, such as reliability, functionality, and safety. Thus, it's the role of the EEF to devise strategies to overcome these complex impediments and help deliver the preferred capability state to the customer for their use.

These complex impediments exist in many forms: physical entropy that causes the aircraft to degrade, human errors in production, maintenance (and sometimes operator errors, too, need addressing by engineering), or supply-chain issues that might cause future hold-ups in aircraft availability. Whilst the EEF may not be employing creativity to create something new, they are using their creativity, inquisitiveness, and ingenuity – their contriving demeanour – to both counter these challenges and impediments, as well as provide the direction and instruction to activate assets/systems to be effective in-operation. It's the style of engineering that helps get the most out of an asset/system/engineered intervention.

28.2.2.3 Keeping state up-to-date

Despite the importance of maintaining a baseline, contriving a preferred capability state is not just a matter of maintaining or defending the status quo – it's about assuring the operator's potential capability remains in a preferred status.

The EEF's role is also to advance the capability state. This doesn't always mean physical or design changes to the aircraft – the mere improvement of the fleet's level of availability and payload reliability, or faster aircraft activation procedures to increase the level of preparedness, can be a significant boost to an operator's ability to generate greater levels of Capability. Efforts, too, to reduce sustainment costs move the capability state towards a more preferred profile.

Of course, physical alterations may also be called for to help advance the capability state towards a more preferred position, and the EEF must also work with the operator to ensure the aircraft system is staying up to date or finding ways of adapting the aircraft's functionality to suit the customer's needs. In a military context, for example, this means whether it can defeat (or at least counter) emerging threats. In the civilian context, this might mean working with in-flight product managers to embody the latest, market-leading customer experiences, as well as ensuring the aircraft are equipped to fly the routes the airline is seeking to establish itself in (this is especially important for having the right equipment and procedures for precision navigation approvals, or EDTO approvals).

Some improvements are about countering threats to maintain an equivalent (albeit different) capability state. This is particularly true of safety enhancements, such as the instance of the Milvus where changing the anti-collision lights could have been enough to prevent mid-air collisions, thus enhancing the safety state (or at least countering the unsafe state) of the fleet.

28.2.3 So what?

There is perhaps not much 'new' insight in this section – it's even susceptible to taking already clear concepts and making them frustratingly obtuse.

However, it does shed some light to the mindset that a Solution-aligned EEF needs to adopt, and represents a core principle to guide its thinking, planning and doing: that it's the agency that ultimately controls, manages and influences the condition of the critical 'tools' a customer needs to do its core job.

There are factors that work against the presentation of a suitable condition, and it's the EEF's role to devise strategies to overcome them, whilst also providing the organisational 'energy' to ensure the preferred state's continued activation. As previously discussed, professional engineers don't do the physical 'hands-on' work but assess the state of the fleet to ensure it's as desired, and direct other aspects of the engineering community (such as maintenance) to rectify undesirable attributes.

As such, the EEF needs to posture itself to take responsibility and ownership for controlling the condition of the utility offered to the customer – a principle that cuts through the rest of this archetype of a Solution-aligned EEF.

28.3 Principle 3: The EEF is characterised as The Solution Sentinel

So what makes a Solution-aligned Embedded Engineering Function *archetype* unique in contrast to a conventional *stereotype*? To get a sense of the difference, Table 12 sets forth 14 contrasting points between the two types.

As stated previously, these represent very generalised positions, and given that there are no exact two engineering organisations, variability is a given. In addition, enhanced commercial pressures to 'work smarter' will likely push any EEF in this type of conceptual direction. However, this contrast will still be insightful in building a leadership vision for any change efforts to build an enhanced EEF.

28.3.1 What is it to be a Solution-aligned EEF?

So, if a conventional EEF can be characterised as a technical agency with responsibility for control and response to technical matters, how can a Solution-aligned EEF be better expressed?

Whilst the key action or verb of an EEF might be a *contriver*, this study asserts another term to describe the 'DNA' of a Solution-aligned EEF. It's a term not normally used to describe engineering, and perhaps doesn't cover the fullness of the EEF's nature that is being described. However, it reflects that engineering isn't always visible, but that it works tirelessly behind the scenes, protecting people, property – and ultimately, interests (whether corporate, individual, or societal). Its effects continue to be seen, even if not recognised or appreciated as such.

This study refers to a Solution-aligned EEF as *The Solution Sentinel*.

Table 12: Conventional-versus-Solution aligned EEF characteristics

Conventional EEF leans toward…	Emerging Solution-aligned EEF leans toward…
Discipline focus	Solution-front focus
Emphasis on working on detailed technical challenges	Emphasis on working on detailed technical challenges in light of other players seeking to address the customer's imperative
Responds to external prompts at interfaces	Strong outreach capability to work with key members in the Solution ecosystem
Solves technical problems with technical solutions	Solves customer problems that are technical in their root nature
Solves problems with technical solutions	Solves problems using technical, logistics, maintenance, or other business solutions
Emphasis on the asset	Emphasis on maximising the value of an asset and the capability it, combined with other elements, yields
Emphasis on technical excellence as end-goal	Emphasis on achieving the business's (and thus customer's) goals through technical excellence
Governance if focused on the integrity of functional discipline	Governance is focused on the performance of the service streams, whilst maintaining the integrity of the functional disciplines
Highly process and procedure driven, with an overriding appetite for compliance	Highly outcome and preferred-state driven. This drives devising the necessary safety & quality-assuring processes and procedures to enable this pursuit. The EEF maintains a strong discipline for process/procedure compliance; however, it also exhibits a routine and initiative for pursuing process/procedure improvements and enhancements to help the Solution ecosystem meet the customer's imperative(s).
An emphasis on performing technical tasks	An emphasis on understanding the condition of an asset/capability-state, and how it exposes the Solution ecosystem to risks in achieving its outcomes (including business risks for the provider, and operational risks for the customer)
Platform management	Service leadership (including platform management)
Oversight 'cost-centre' activities	Lead value-generation efforts
A tendency to be inward-looking, controlling what's in their domain of responsibility	Without disregarding their domain of responsibility, posture themselves to be more outwards-looking and focused on a capability goal.
Managing a transactional business relationship via process-based workflow	Cultivating and developing a business partnership via collaboration and process-based workflow

28.3.2 Introducing The Solution Sentinel

A sentinel is generally referred to as "A soldier or guard whose job is to stand and keep watch" [223], which sounds a bit static, but which does reveal an important role of the EEF: constant vigilance to protect. However, with a little imagination and sense of intrigue – such as in the 2006 thriller of a similar name – it can also refer to an operative who works behind the scenes to make things happen.

It's this sense of being an effective agent of safety guardianship, a defender against complex impediments, and a contriver of a preferred capability state for which the term *Solution Sentinel* is intended to reflect.

28.3.3 An EEF with an enhanced posture

If there is one key difference between a conventional and a Solution-aligned EEF, it's found in its organisational posture, as reflected in the service posture concept expressed in Chapter 23. Namely, a Solution-aligned EEF has a more proactive stance and a more dynamic disposition.

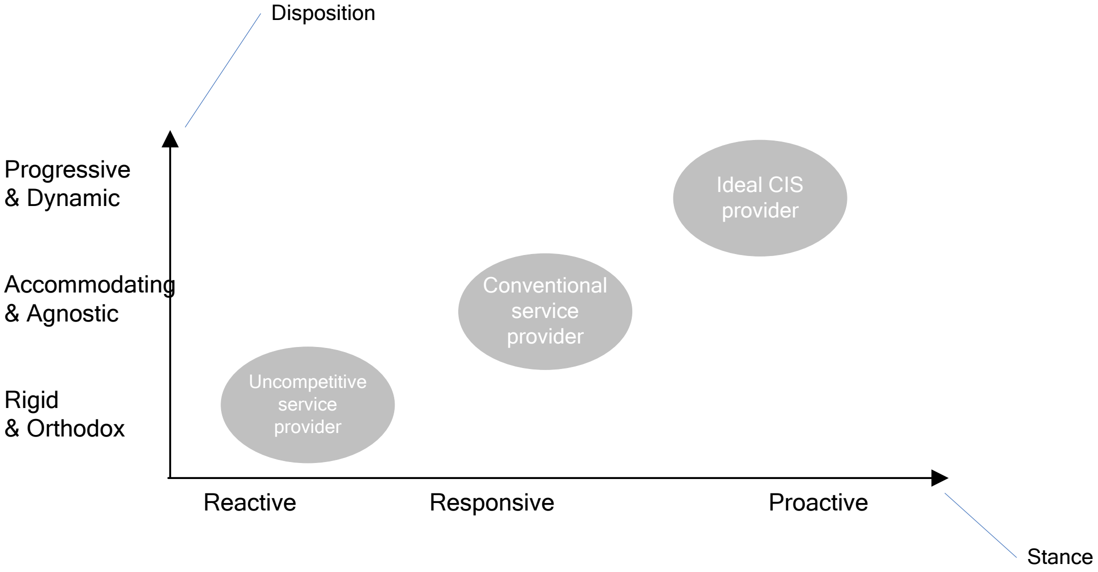

Figure 97: Service posture model from Chapter 23

In practical terms, it reflects a more 'business-savvy' approach that has a dynamic and transformative disposition – a high level of energy to improve the customer's (and the provider's) condition, and reflects the following characteristics:

- **Connected-in:** An organisational unit that does not work in isolated, but is instead part of a coherent, integrated ecosystem that's focused on the contrived state of the technical solution. In addition, instead of being an 'isolated' technical unit that's disconnected from the more strategic affairs of the business, it's highly connected to it.
- **Mindful:** A unit that's very mindful of the impact its work has on the business and is also savvy enough to work accordingly, without 'dropping the technical excellence ball.'
- **Closer:** Reflects a situation where the EEF is in much closer proximity to the customer, as well as other traditional engineering community units (such as maintenance). It has a seat at the leadership table with an active voice, rather than merely 'taking orders.'

- **Multi-roled:** Instead of responding to purely technical queries (whether from other technical units, such as maintenance, or as refined and specific queries from commercial interests across the company or the customer), a Solution-aligned EEF actively enmeshes itself in helping solve challenges of a business nature too.
- **Proactive:** While the EEF is not exclusively a business problem-solving function (nor the only such unit, with other business improvement units or leadership teams generally playing a leading role in such effort), the EEF doesn't wait to be contacted by these commercial/business interests. It's listening, engaging and collaborating with these other aspects of the ecosystem, including the commercial imperatives of the provider firm, as well as the operational imperatives of the customer, finding ways the EEF can contribute (especially where it involves the capability state).
- **Solver:** The EEF puts itself forward as a unique resource that can affect change and improvement to the Solution ecosystem, advocating its capabilities to the various leadership and functional units within the provider and the customer.

Furthermore, a Solution-aligned EEF also adopts a proactive stance. This refers to the fact that a Solution-aligned EEF:

- Might engage in a consistent 'firefighting' mode, but has the requisite capacity, ability, and preparation to deal with the complex and often non-routine challenges thrown at it. In doing so, it helps the Solution provider to deliver a smooth and integrated delivery profile, even though circumstances (such as scheduling issues, supply issues or unexpected reliability problems) might easily distort this profile;
- Recognises that they operate on multiple fronts, and has built its work program to be effective against multiple, simultaneous challenges that often compete for the limited attention and resources of the EEF;
- Has adopted an organisational persona and routines that help it be successful in the face of this enhanced, transformational and sentinel expectation set.

It becomes clear this framework is a combination of traditional support, operations and maintenance engineering responsibilities, along with the extra commercial and service requirements that a Complex Integrated Solutions approach might drive. These last two factors are points that are expanded on over the next two sections, and highlight a more business-savvy management methodology for a Solution-aligned EEF.

28.4 Principle 4: The EEF operates across four simultaneous fronts

Whereas a conventional EEF organises itself around core engineering and technical disciplines, a Solution-aligned EEF considers not only the technical content of its work but also the nature of it too. In particular, it recognises that there are four key threads or fronts to its work of contriving a preferred capability state:

1. **Airworthiness & Safety** – Aimed at delivering safety outcomes
2. **Availability** – Delivering support for seamless, daily operations

3. **Capability & Operations Development** – Responsible for devising and executing improvements and enhanced capabilities
4. **Smart Ownership** – Delivering an effective, long-term, value-focused ownership experience.

These four areas represent groups of challenges across the capability solution – that is, the contrived preferred state. They are key areas of focus for the EEF that require close, simultaneous attention that can make a real for the rest of the Solution ecosystem in addressing the central customer imperative. As should be clear, the EEF does not work in isolation, but rather is part of a broader, integrated group with the same goals.

It's also important to note that these are four key programs of work, each with a unique outcome. They may not necessarily be challenges organised into team structures (although the first case study exhibited something similar), and they don't replace traditional engineering functions (structures, systems, propulsion, etc.). Instead, these threads help align these technical competencies towards producing outcomes and effects that help the broader Solution ecosystem. In addition, it reflects that the nature of the EEF's work is based on technical and scientific knowledge, but is deployed to address business needs.

Figure 98: The four simultaneous fronts of the Solution-aligned Embedded Engineering Function

28.4.1 Front 1: Airworthiness & Safety

Ensuring aircraft airworthiness, and supporting a continual quest for operational safety, is the bedrock of any aviation operation. Further still, airworthiness issues not properly managed by a sustainment Solution provider can be an immediate deal-breaker with any customer.

As such, the Airworthiness & Safety front is entirely devoted to ensuring the inherent airworthiness of the contrived capability state and supporting efforts within the customer to ensure the safety of flight operations. It's the EEF front that is devoted to pursuing safety outcomes.

This front's work program sees the EEF as a contriver of a preferred, safe capability state – the qualities and inherent nature of the fleet and individual aircraft that means operators can fly the aircraft with prolonged confidence in the aircraft's ability to behave as expected. However, whereas maintenance units will declare airworthiness, the EEF is engaged in shaping how it manifests.

It does that by engaging in the concepts outlined in the previous chapter, including:

- **It patrols and controls the sphere of safety:** The EEF generally will control who, and how, the aircraft will be physically engaged with and altered. However, it also has final control over what design changes are to be executed on the fleet, as well as monitoring what goes on inside this conceptual sphere of responsibility.
- **It engages on all three of the stratified airworthiness levels:** This includes supporting maintenance efforts in the enacting of airworthiness (particularly through interpretation of maintenance tasks, devising repairs, and issuing improvements to the Technical Management Policy), and monitors how the capability state is behaving and manifesting (the basis of which may trigger investigations and other analysis when issues present themselves in-service).

This front works in a capacity similar to that of an intelligence agency – monitoring vast sums of information, scanning for threats, and devising interventions to contain and dispel any issues. On an activity level, the Airworthiness & Safety front's work program is composed of several ongoing and repeated tasks, including:

- Reviewing incoming technical information items (including OEM service information, defect reports, occurrence reports, and other sources of information into the EEF)
- Assessing, devising & promulgating authoritative directives to operators, maintenance providers, and logistics providers
- Technical investigations
- Operational incident investigations (when requested)
- Implementing and operating the engineering governance system (the regime of approvals, including who, what scope of authority, and transparency of technical decision making)
- Logging and managing identified hazards (including system safety programs), working with other Solution ecosystem and support network members to bring the risk to an acceptable level (whether it be by operational limitations, procedure changes, changes to maintenance tasks/inspections, or design changes)
- Auditing and oversight of Solution units that require technical reviews (as opposed to pure process auditing).

In addition, the Airworthiness & Safety front is the ideal space to foster the conventional technical expertise structure (in other words, the 'brains trust') for assessing the technical merits of all matters presented to the EEF. As such, this makes the A&S front the ideal 'control point' for the EEF to act as the final technical authority on all matters that the EEF engages in. This means having an oversight (or at least visibility) of all the other fronts' work program, holding the ultimate veto right over any decision, direction or recommendation issued by the EEF. This also means all uncertain or contentious matters faced by other EEF fronts should be presented to the A&S front for final decision making or adjudication.

28.4.2 Front 2: Availability

Whilst actual process of 'handing over an available jet' – such as the allocation of aircraft tail numbers to operations, maintenance planning, and other 'live' operational factors – are normally the responsibility of other units in the Solution ecosystem, the EEF has a seminal role in facilitating these units to carry out their functions. The EEF can play a make-or-break role on the operational front, and thus a Solution-aligned EEF will have a focus on managing availability and supporting other operational demands.

Thus, the Availability front is highly focused on devising quick, implementable solutions to ensure that an aircraft can return to service as soon as possible, as well as working to prevent 'outages' that render an aircraft unserviceable. It's a work program that's highly in sync with the operational tempo of the customer and is aimed at helping other units maintain target levels of aircraft availability. This can be achieved through activities such as:

- Analysing damage and unexpected defects, making a unique determination as to whether the aircraft can continue to fly unrestricted, or with limitations, or whether it must be repaired before next flight
- Helping return aircraft that have gone unserviceable at the gate/flight-line by identifying, assessing and approving logistical workarounds, such as cannibalisation (this also can occur in the scheduled maintenance environment)
- Providing repair schemes to defects identified in the course of maintenance, prioritised in a way to ensure the aircraft leaves the maintenance slot on time
- Directing or advising pre-emptive action to help secure aircraft availability, such as an interim practice of removing an LRU before its actual scheduled removal (to pre-empt a failure on a unit that's manifesting an above-expected failure rate), whilst the cause of the reliability issue is investigated
- Identifying key availability 'threats' (namely component reliability issues) that threaten a smooth capability availability profile (the actual rectification of such issues is part of the Smart Ownership front).

It's a work program that's also highly sensitive to its constitute client's needs, prioritising demands from maintenance invigorators (the fleet management and planning functions), maintenance providers, and operator units to help achieve the availability target. However, this Availability thread also acts as a catalyst to help influence these clients to adopt measures that both return aircraft to serviceability, but also pre-empt issues that could affect future availability. It also catalyses other threads of the EEF to do their part to secure aircraft availability goals.

28.4.3 Front 3: Capability & Operations Development

Whilst the Availability thread is focused on attaining daily, operational serviceability targets, the Capability & Operations Development thread adopts a more medium to longer term perspective.

Capability & Operations Development is focused on a more strategic role of working with the customer to enhance its effectiveness. It represents an extensive enhancement work program that is mindful of the fact that the customer's need evolves, and also that the customer will have an interest in exploiting new technologies, tactics, and techniques for an operational and business advantage. It also deals with other improvements and changes that will affect operations, at the very least, the delivery and oversight of any potentially impending changes dictated by other EEF fronts.

Whereas other fronts seek to contrive a preferred capability state through control of threats or smart workarounds, the Capability & Operations Development front is focused on developing the existing capability state as the customer's imperative morphs and changes. As such, it has a more project management aspect to it, although also retains a strong service and advisory element too. It also projects itself as the custodian of many of the operational aspects of the aircraft Technical Management Policy, as well as acting as a final authority on technical matters beyond existing steady-state operations.

This EEF front includes activities, such as:

- Major platform upgrades, such as a substantial pilot-aircraft interface upgrade to align to the next generation of front-line fighter for the customer enterprise
- A more tactical adaption of the aircraft, such as installation of new visibility measures to boost flying safety in crowded airspace or at remote airfields
- Development and oversight of embodiment of in-flight product upgrades, or new mission equipment (including associated operational procedures)
- Assess and approve potential operational changes or deviations from the flight manual to permit a different style of operations, such as alternate tire-pressure specifications to operate off different runways
- Trade studies of alternate roles the aircraft takes on as a result of doctrinal-level changes to military strategy, such as the use of a manned aircraft in coordinating unmanned assets in the battlespace
- Acting as the control point for updated training data
- Issuing operational recommendations or advice to operators to incorporate into their own procedures for improving aircraft efficiency performance
- Provides data-driven insights back to the operator on the status of the fleet, such as in the case of the Milvus of how the fleet was being flown, and which crews were pulling more aggressive manoeuvres.
- Responding to customer requests for interpretation support of technical publications and other Technical Management Policy items.

Capability & Operations Development is also the ideal control point for two critical EEF activities, namely:

- **Publications management:** Technical publications change in light of safety investigations, clarifications requests received from the customer, new equipment installations, or other changes in circumstances to the capability state. The EEF is responsible for managing, controlling and distributing approved publications as the definitive source of truth for the aircraft and represents an important aspect of capability state.
- **Performance engineering:** As already alluded to, providing assistance for new routes or seeking ways of improving fuel burn are activities highly aligned with this front.

28.4.4 Front 4: Smart Ownership

The term 'Smart Ownership' may be a bit nebulous and perhaps implies marketing speak. However, this front is focused on longer-term initiatives that can result in some very tangible benefits for the Solution provider, as well as the Solution customer – namely financial and time savings. It devises and implements strategies to manage the fleet in more cost-effective ways and to defend against (or at least help contain) emerging impediments that would increase the costs of operating and sustaining the capability state, reduce availability, and/or reduce effectiveness.

It differs from the Capability & Operations Development front in that it's a more 'internal' effort, one that operations staff/operating crews generally won't be affected by (unless this front is not properly managed). However, other segments of the customer community will appreciate its efforts.

Key activities can include:

- **Reliability improvement initiatives** (with a commercial/service outcome, rather than safety): Efforts and initiatives, such as maintenance policy changes, or working with the Type Design Group/Holder to devise design fixes to arrest any negative reliability trends to contribute to a smoother availability profile. The ongoing activity of reliability analysis thus sits under this front's work program and enables effective reliability interventions.
- **Cost management:** Including cost modelling, cost driver identification, cost profile monitoring, and cost reduction initiatives. This line of activity also involves process improvement efforts to reduce expenses, as well as providing data and intellectual support to cross-Solution initiatives to reduce costs (such as providing updates to the customer on the remaining life left in the aircraft structures, as part of structural health assessment processes).
- **Maintenance program reviews:** Whilst ultimately under Airworthiness front control, maintenance program reviews can also help optimise maintenance schedules and be used to justify a less restrictive inspection regime (where the data supports it). In addition, large-scale review projects might be placed under this work program for resource devotion purposes.
- **Obsolescence management:** Maintaining relationships with the supply chain and support network, monitoring for any likelihood of emerging obsolescence issues. This includes examining what impediments may arise in the medium-to-long-term that might affect supply of critical parts and data, and devising interventions to arrest the impact of such disruptions.
- **Retirement and fleet advice:** Undertaking analysis and modelling of fleet withdrawal scenarios, as well as examining life-extension options.
- **Support to other process improvements:** Where the EEF reaches out and provides assistance to other aspects of the Solution community, such as finding and approving ways of changing actual maintenance tasks (and not just the frequency of them).

This front could be misinterpreted as purely as a continuous improvement portfolio (which, in a significant manner, it is). However, it also has a pre-emptive posture to identify, understand and counter longer-term issues that might impede Solution success, but also work to help smooth out perturbations that affect the quality of capability state ownership[45] & use in the longer term.

28.4.5 Why distinguishing these fronts is important

Whilst these four fronts might appear to be somewhat obvious and are composed of activities already undertaken by conventional EEFs, the question must be asked: why have four distinct fronts?

[45] Of course, the capability state might be leased; nonetheless, the capability state is still under the jurisdiction of a customer. It's the sense of control and 'enjoyment' of capability state, rather than property rights, that's intended by "ownership"

The key answer is found in experiences both organisations in the case studies experienced, namely loss of focus with competing priorities. As the nature of the EEF is to be engaged in a complex myriad of demands, issues, and challenges, urgent matters can often trump[46] important ones.

Hence, explicitly defining the nature of the challenges, expectations, and demands that will be placed on the EEF helps give visibility to those complex (and often competing) needs. This then helps an EEF structure its work program – and likely its resourcing and team structures – to be readied to meet the demands faced on these key fronts. This means both pressing matters, as well as important long-term matters, can be given the attention they deserve, whilst having a lower risk of dropping the ball on one of them. This also permits an emphasis on helping meet business needs, while not compromising on safety imperatives.

28.5 Principle 5: A Solution-aligned EEF exhibits five dominant personas

Beyond the four fronts of challenges and responsibilities, it's important to consider another angle when characterising a Solution-aligned EEF: a renewed organisational persona.

This Solution-aligned archetype is far more than an 'output agency'; so how can it think of itself and, in turn, then project its true form to partners and stakeholders that it engages with? What follows are descriptions of the five dominant personas that articulate this alternate EEF archetype, compared to a *specialised technical control and response unit*.

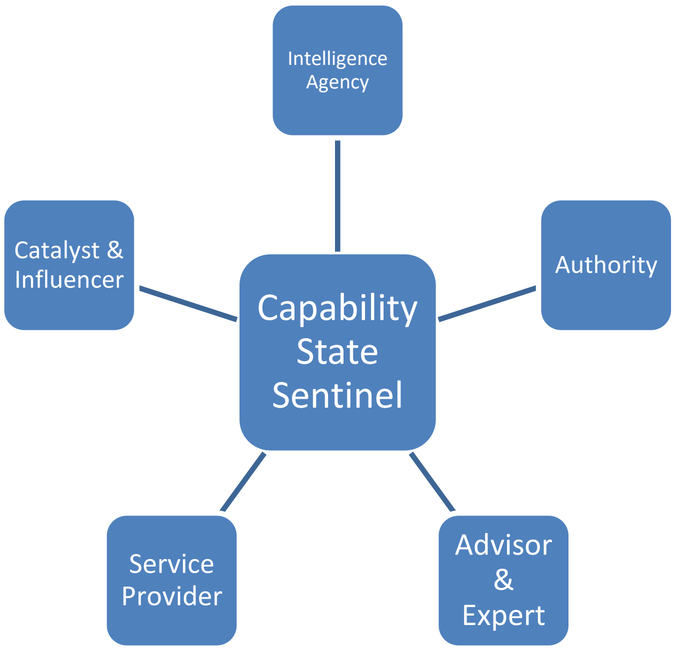

Figure 99: The five key personas of a Solution-aligned EEF

[46] This is not to say important safety efforts are misplaced; they likely turn into combined urgent AND important ones

These personas could be roughly explained as a style of corporate behaviours, qualities, and systems-of-activity. But they are also external and internal identities: what external partners can expect when dealing with the EEF (and to understand their unique role in the sustainment Solution ecosystem), as well as an internal model of the styles and nature of the work the EEF is engaged in. If engineering is taught as primarily a technical profession, understanding that it's deployed in unique modes requires further annunciation as to what's expected of those modes.

These 'corporate behaviours' aren't set in stone, and an actual EEF's corporate persona will be dictated by the culture, leadership, and environment of that exact situation. Instead, these five-dominate personas represent an archetype – qualities that an EEF may seek to emulate as an end-state for any transfiguration effort to become a more Solution-aligned operation. They're an aide-mémoire to a corporate vision, but require interpretation and thought before applying directly into an organisational context.

However, examining each of these personas helps paint a picture of an integrated characterisation of a Solution-aligned EEF, and reveals the distinctive facets of The Solution Sentinel.

28.5.1 Persona 1: Intelligence agency

A key persona the EEF takes on is that of an 'intelligence agency.' It's a persona that's recognised by the 'intelligence cycle' of information gathering: threat detection, devising of strategies for nullifying the threat (whether a 'big bang' or a watch-and-act approach) and intervention evaluation.

It's both an important persona, but also a critical mental routine (as illustrated in the previous chapter on airworthiness). It's the style of inner workings in the EEF that enables it have very dynamic, timely and accurate mental models. By constantly evolving and updating mental representations of how the world around the EEF is working and moving, it can formulate and devise interventions for the benefit of the Solution ecosystem, including the provider and customer.

It's a persona that's reflected through the following styles of work the EEF finds itself engaged in (whether aware of it or not):

- Operating a vast regime of information collection and gathering, whether by a more regular means (e.g., maintenance record analysis) or through more manual and non-routine means (such as occurrence reporting). It also has its own network of relationships with the aircraft Type Design Holder, as well as other sub-system OEMs and other supporting or specialist engineering outfits that contribute information, as well as sense-making, to the EEF's cognitive efforts.
- Utilising this network of information and knowledge to monitor the capability state, and to identify any potential threats, whether airworthiness hazards or other factors that could affect the goals of the Solution ecosystem such as aircraft availability or payload reliability.
- Combining information together to scan and look for evidence of threats – whether latent design issues with the aircraft affecting airworthiness, to potential support issues from subsystem OEMs in the longer term.
- Devising strategies and interventions that can be enacted to contain the complex impediment or threat that is emerging or persists against the capability state, or the broader Solution ecosystem (via the capability state)

- Evaluate strategies to ensure they remain effective or improve these interventions (especially if they are persisting ones, such as a new procedure, maintenance task, or design-change – sometimes changes made can induce new issues, such as found with the APU situation on the Milvus).

The EEF might not always be at the coalface of problems or issues that arise (this is often the flight crew or maintenance units). However, it's a key hub in an information and knowledge sharing network, and in a behind-the-scenes manner, is active in identifying and defending against threats of all kinds.

28.5.2 Persona 2: Advisor & expert

The EEF is the resident 'brains trust' for tackling deep and complex problems, mostly of a technical nature, and exhibits an innovative problem-solving persona. It has the requisite technical capability (or by knowing the limits of its abilities, seeks assistance from its support network) to analyse, devise and issue authoritative advice and/or directions for non-routine matters that enhance (or retain) a preferred capability state.

It does this via several means, including:

- Devising interventions and ways of solving technical problems – whether by technical means or by workarounds
- Conducting feasibility studies and research to advise on the scope and practicality of proposed improvements to aircraft or procedures.

However, it's not just the internal effort to the service provider persona (as illustrated in Persona 4), nor is it the solver of problems just submitted to it. An EEF will actually think of themselves as a critical advisor and consultant to business management functions across the Solution ecosystem (namely the provider and the customer), as well as other units and elements of the Solution. It may not be done on a commercial basis (i.e., as a paid consulting task); however, it's a disposition taken by the EEF to advance the aligned interests of the Solution ecosystem.

Figure 100: The EEF's constituent clients for which it provides advisory and consultancy-style services

The EEF exhibits that disposition of 'reaching out' (or at least exhibiting greater visibility of its presence and willingness to assist) to members across the ecosystem, and keeps an eye on the big picture, seeking where the EEF can support the rest of the business, and the CIS ecosystem. It's this disposition which leads to the next facet of an EEF.

28.5.3 Persona 3: Catalyst & influencer

Rather than acting as an 'input-output' processor model, the EEF is an energetic group that seeks to influence and collaborate with other parts of the business and Solution ecosystem to ensure it remains a solution to the customer's imperative (or at least from a capability state perspective).

Whilst a Solution provider will have other means of engaging with the customer to deal with other facets of a Solution (such as service order demand and fulfilment, fleet planning and the management of interactions between the provider and customer), the EEF exhibits its own active posture. This means that it initiates conversations, data-sharing, insight-sharing, but also reaches out to other units and aspects of the Solution ecosystem to improve (or at least, stabilise) important matters.

It can also mean other activities as well, including:

- Reaching back to the aircraft manufacturer to advocate for design changes or technical data to improve the capability state of the fleet
- Collaborating with maintenance units to improve maintenance task efficiency (not just scheduling, but the actual step-by-step performance of maintenance tasks).

This is the facet of the EEF that puts ideas and initiatives into action and motivates others for the sake of the Solution ecosystem's success. It helps bring the Solution 'to life' with its proactive and outwardly-orientated posture.

28.5.4 Persona 4: Service provider

The EEF is a critical service juncture for other members and units across the Solution ecosystem, with service request demands being placed on the EEF for various decisions, analyses and other outputs. As such, the EEF is a 'task cruncher' by retaining the output activity of conventional EEFs, and serves several constituent clients, including:

- Maintenance venues who put in requests for repairs, clarifications or other technical support
- Operational units (namely flight operations) for specific requests or queries
- Customer business management/leadership for feasibility requests or longer-term fleet management advice.

However, the approach is different to a conventional 'black box' approach. Instead of having a request/prompt inputted to the engineering management process with a response then outputted, a Solution-aligned EEF adopts a *service-driven* persona. Such an approach places an emphasis on the following:

- Creating a two-way street based on relationships rather than a reliance on interfaces. Where appropriate, the response is more collaborative.
- A greater capacity for listening to the need and understanding the context of service/demand requests to assess priority, as well as understanding the true root of the need (and potentially offering a more effective solution).
- Because of these relationships, an enhanced ability to prioritise taskings, keeping the big picture in mind.
- An ability for professional empathy to keep customers informed about the progress of requests, mindful of where the request sits on a critical chain of events that may impact operations. This includes extra mindfulness of required timeframes.

28.5.5 Persona 5: Authority

The EEF, whilst having these more 'business friendly' personas, still does need to retain a sense of being an authority. Ultimately, it is the EEF that enforces the sphere of safety around the aircraft fleet, setting the standards and entry-control for what may alter the state of the capability Solution, and otherwise defining the envelope of safe and reliable operation.

On a practical level, the EEF operates as an authority in that it:

- Issues instructions and directives that must be followed – the 'thou-shalls' that must be complied with and implemented (e.g., the systemic maintenance program to be used, the stipulated method of performing particular tasks, or the appointing of particular datasets to be used)
- Is the final and definitive word on technical matters. Even though the Solution-mindful EEF considers the negative commercial impact a decision might have, it operates at a higher level, mindful of the other negative consequences of not 'laying down the law,' such as safety or legal implications.
- Exerts strict control – the EEF possesses the dictatorial right and power to decree or change matters (in its scope of authority) when it deems this is necessary. This may involve grounding

aircraft, approving or revoking certain organisations or individuals to participate in the maintenance or support process, or having the final word on changing a procedure.

28.5.6 Why is this important?

Being clear about the EEF's personas – the differing styles of how the EEF engages with those around them – helps to demystify the EEF's role, plus helps make its role and its value proposition clear to partners and stakeholders. The professional engineering practice in this environment is multi-faceted, and perhaps not always understood by partners, or even by the outfit itself (especially given the lack of specificity with a lot of definitions and conceptual understanding of what engineering actually is). Thus, asserting the multi-role and multi-natured quality of the EEF outfit is instructive to build a clearer vision for other EEF's considering the transfiguration journey.

28.6 So what?

What is to be gained from these deliberations? Is it really all that important to be spending time thinking about this concept? This study asserts two reasons:

- It can be used for thinking about transfiguration efforts
- It may just be an important production-versus-protection circuit breaker.

28.6.1 Its use as a concept

As previously indicated, the Solution-aligned EEF concept does not dismiss a conventional approach outright, instead building upon foundations that are essential to aircraft sustainment. However, what it does do is grow these fundamentals to reflect a concept more accommodating to the realities that EEFs face in a highly commercial, performance driven environment such as a CIS. It's also to give managers and leaders a template or vision of what an EEF could be, and some of the corporate behaviours and attitudes that could and should be cultivated to shape a more business-focused EEF that still maintains a sense of independence and technical integrity.

28.6.2 A safety circuit breaker

This archetype has been devised on the assumption that if an EEF can be better prepared to deal with the pressures of corporate expectation and performance imperatives, the more likely it can alleviate the pressure on truly safety-critical decisions. By explicitly understanding that the EEF has other responsibilities beyond safety, and builds a work-program, routine and 'organising' around these expectations so that they can be performed without impeding on the safety requirement, it gives the EEF every chance of more effectively balancing the protection-versus-production conundrum

In addition, if the EEF can genuinely help the business (rather than merely be an 'output supplier' to it), it builds trust and 'political capital' so that when the EEF must assert a disruptive position on a matter for safety reasons, there's less of a chance of it been seen as merely an entity that is obfuscating. Rather, by being a genuine partner, it more likely endues the EEF with credibility so that its less-than-favourable views on an issue that presents a genuine risk can be taken seriously and acted upon with the support of the Solution's management regime.

28.7 A new perspective

Before observing this concept of The Solution Sentinel as an ideal archetype for all sustainment Embedded Engineering Functions, it's worth asking the question: is this a complete archetype?

The answer is *probably not*. There are undoubtedly other examples, experiences, and perspectives that would inform and fill-in this quest for a more sophisticated management thought on structuring and running an Embedded Engineering Function. It's an intellectual space that's only enriched by the contributions and stories of other professionals.

However, this concept of The Solution Sentinel does set down that in-service engineering operations, particularly at the EEF level, are complex endeavours that cannot be reduced down to product-centric problem solving or technical administration. They operate over several fronts, from safety, to cost-management, to being the 'operator's keeper,' and in a variety of ways, from a notion akin to an intelligence agency, to that of a clever advisor. All the while, they operate with a style of work that is behind-the-scenes, but that yields front-of-stage results, contriving the necessary circumstances for a customer to deliver a stellar performance.

This is what's meant by Spanners to Suits: having an EFF optimised to a CIS environment isn't just about solving technical issues; it's about empowering an operation that delivers business outcomes for a customer. And it's explicitly set up that way without any reservations or shame.

Overall, what this concept of The Solution Sentinel provides is a more grounded starting point that can be the basis of more sophisticated management thought, both about a management methodology for Complex Integrated Solutions, and for Embedded Engineering Functions steeped in a Solution paradigm. As with all perspectives, they inspire seeing problems in new ways, or even just to highlight that a non-optimal situation exists. It gives power to managers, leaders, and professionals to assess their situation through a different lens and see how their own context adds up. It opens up new possibilities and helps promote innovation and positive change. It can also be a point of helping the same people see the strengths of their existing arrangements, and understand not just what works well, but why it works well, too.

Part VI

A new flightplan

CHAPTER 29

On Finals

Recapping this Study, and an Implementation Framework

29.0 A long journey

Through the forest of foundational concepts, to the valleys of the case studies, to the mountains of the insights generated from the case studies, this study has been a long – and at times, philosophical – missive. So how does one resurface from the ideas and insights generated in this piece, and start to construct a management methodology?

To aid the sustainment and Complex Service Program practitioner, it presents an implementation framework that helps position some of the key concepts into an operative context.

29.1 What has been learned?

First, it's worth quickly recapping some of the main observations and ideas generated by this study, especially given its size.

29.1.1 On Complex Integrated Solutions

This study has found that sustainment-focused Complex Integrated Solutions exhibit several characteristics:

- are much more than just a maintenance business
- are complex, and have no textbook
- must be designed and delivered in way that is predicated on benefits, not just activities
- need a clear business model, and subsequent operations model
- can cause enterprise alignment challenges when Solution providers seek to capture value from such Complex Service Programs
- building a more nuanced and sophisticated picture of the customer organisation can present a challenge

- success is not always evaluated by performance metrics alone
- they involve evolving relationships
- they're bespoke by nature rather than being catalogue-like offerings
- they require active management of airworthiness and safety, especially given the commercial imperatives involved
- see ageing aircraft management as an important consideration.

In response to these observations, this study has put forward a series of core thoughts that help build a core-reasoning around the Solutions business activity typology. These include:

- Solutions (in this context) are more than marketing terms, tailored proposals, or transactional or commoditised service programs
- Instead, Solutions are built around a critical customer imperative. Capability generation is an example of such imperative.
- Solutions are realised as ecosystems
- Solutions seek to enhance customer condition
- Solutions success needs to be measured from the emergent narrative, and not just the metrics
- Solutions are organic, not mechanistic in nature, and are the goal is to establish dynamic steady-state operations
- Solutions need strong delivery management systems tempered by an ongoing service strategy. This includes the need to develop a Solution Management Framework, a Solution Development Strategy and a Solution operations model
- Solutions require a long-term management posture, ideally looking ahead on three key horizons
- Solutions require an active service posture where it has a progressive disposition and a proactive stance
- Solutions demand a renewed logic that is highly service-orientated, rather than be a transactional project of activity driven by product-centric thought
- Solutions are better understood as existing in one of three key states – nascent, transient or steady – and that the segmented journey to a steady-state operation constitutes a Solutions 'state-cycle'.
- Complex Integrated Solutions can be defined *a business activity typology to identify, source, develop, integrate, implement, energise, deliver, enhance, refine, optimise, sustain and support all the elements required to meet a customer's imperative, established as a coherent ecosystem with the customer, and provided in an economically viable way*.

29.1.2 On engineering in the in-service environment

Within this newly postulated context of Complex Integrated Solutions, this study also made several findings with relation to the role of engineering, namely as expressed as the Embedded Engineering Function. Key observation includes:

- Identifying the Engineering Function attached to a sustainment Solution operation isn't always straight forward
- Professional Engineers play a sentinel role in in-service Solutions and their success
- Engineering in the in-service environment doesn't always involve conventional technical work

- Product-centric definitions of engineering do not convey the value and deep-seated effort that it brings in the sustainment Solutions environment.

To address these observations, this study has put forward a number of frameworks and definitions to help build core-reasoning in this more detailed area of Solution delivery. Key ideas include:

- That existing Embedded Engineering Functions are the product of default thinking, including regulatory requirements and functional structures.
- This results in a conventional approach to devising an EEF, and there is a need to improve – and transfigure – the concept to be more relevant for CIS operations.
- That to be more encompassing of engineering operating in other modes, including sustainment and in-service support, it must be understood and defined from the effect it yields, rather than the product it outputs. As such, this study has reframed professional engineering as a contriving a preferred state or situation achieved through scientific and technological means.
- In the context of aerospace sustainment Solutions, a major facet of this 'preferred state' is working to ensure (i.e., "contriving") a fleet of aircraft are in an airworthy condition.
- However, as central to the role of engineering in the in-service environment as it is, airworthiness management is not a concept with a great deal of non-regulatory coverage and thinking. Hence, key ideas presented in this study, including the concept of the 'sphere of safety,' that airworthiness is about confidence (not just compliance), and that it's more than hardware safety.
- That the Embedded Engineering Function in a Solution-aligned environment is best thought of as the 'Solution Sentinel', rather than as a technical problem-solving unit. As a Solution Sentinel, it's devoted to contriving a preferred capability state (e.g., a fleet of aircraft) and protecting safety, operational and commercial interests by being focused on several fronts at once: airworthiness, availability, capability/operations development, and smart ownership. It also accomplishes this by recognising that the EEF exhibits five key roles: intelligence agency, authority, advisor, service provider, and catalyst/influencer. It's a characterisation different to conventional engineering formats.

29.2 A new organisational form

So how does the practitioner apply these insights to their Solution operations? To assist, this study poses an implementation framework.

This implementation framework is predicated on a core thought: namely that it forms part of a larger corporate transformational effort to move beyond a manufacturer identity, and towards a more multifaceted organisational concept.

There's little stopping traditional aerospace & defence firms from offering Complex Service Programs, such as Complex Integrated Solutions, with little alteration to the 'mothership's' corporate structure and strategy. In other words, 'bolting on a service offering and just turning it on.' However, as previous research has indicated, this is not an effective or sustainable proposition, with a services approach having subtle, but very real differences in approach to traditional product-centric development and manufacturing efforts. Thus, realising the opportunities presented in a market demanding increasingly sophisticated services requires the morphing of the corporation's overarching strategy and corporate make-up.

29.2.1 Beyond the factory identity

This is not to suggest a wholesale realignment of a firm that forsakes its manufacturing and technical heritage in favour of a service-first one (although some circumstances might call for this approach). Rather, it's recognising the fact such firms are more sophisticated behemoths than a mere production line. As expounded in Chapter 3, this 'factory identity' does not do justice to the manifold nature of the modern aerospace & defence firm.

What the rest of the chapter presents is a framework for the alteration – or, more correctly, the adjustment – to the firm's DNA to accommodate Complex Service Programs, such that they are seen internally as on-par with existing product-centric efforts (that is, services are not seen as secondary, but as primary sources of business for the firm). Whilst the firm might still identify as a systems manufacturer, this framework suggests firms start to identify – via internal dialogue, thought and action – as a multifaceted conglomerate[47] that embodies a wide repertoire of capabilities. This includes erudite service capabilities.

This also involves redefining the term 'manufacturer' from the adjective, to a verb; from an identity, to an organisational activity. It's a concept in which there is a parallel to be found in the agricultural sector. The concept of 'farmer' has changed from a physical, individual cultivator, to that of a logistician, an agricultural scientist, market speculator, asset manager, supply chain coordinator, finance manager and climate modeller. Whilst the physical cultivation is still a key activity, the notion of being a farmer is now far more multifaceted, and no longer identified just from the one activity.

It's this logic that underpins a recommended movement to a multifaceted understanding of the aerospace & defence firm. In addition, the term *conglomerate* comes from the Latin *conglomeratus* which means 'to roll together, concentrate, heap up,' and is derived from other terms meaning 'to gather into a ball [232].' This is a useful mental analogy – firms that bring together in the one organising[48] network [60] a range of different capabilities, market offerings, and related business activity typologies to profitably meet the needs of their customers.

However, the question remains, how can this organising network be adapted to host and cultivate Complex Service Programs, including Complex Integrated Solutions?

29.3 The implementation framework

So how can these insights be deployed in an aerospace & defence firm? Naturally, they can be used by individual practitioners, something discussed in the concluding chapter. However, this chapter proposes a framework to place these insights into some sort of transformative context.

What follows are high-level recommendations that help implement and operationalise this study's findings, from the perspective of adjusting an aerospace & defence firm's makeup to be more service-capable. In fact, the aim is **a complex services-aware & capable aerospace & defence firm.**

This simply means that at the very least, the firm:

[47] Even if the firm is not S&P500 sized
[48] Using Weick's concept of an organisation

- Places at least an equal value on services, as well as products (that services are a 'real business' and not merely a 'bolt-on')
- Adopts at some conscious and dialogue-based levels an explicit reference to service concepts (that is, is aware that there exist differences between operating a product business, and a service business)
- Has an ability to compose and operate a complex service program, such as a CIS, using different approaches to product-centric activities. This includes having the requisite procedures and business development nous to offer well thought-through service offerings.

These are not strictly recommendations established from thorough research, nor are they by any means thorough or complete – there are plenty of other actions and considerations that need to be addressed when embarking upon such an endeavour which are worthy of entire research efforts. However, these recommendations are highly influenced by the research undertaken in this study and were developed in parallel to the insights generated in this study. In addition, they're informed by prior research described in Part II.

29.3.1 Four key facets

This framework is composed of actions and recommendations on four key facets:

- Enterprise strategy
- Organisational Design
- Cultural & Performance Leadership
- Governance Structures.

They're highly connected, but separated out to make recommendations a little clearer.

Figure 101: Implementation framework

29.3.2 Company strategy

The first key facet is that of Firm Strategy. This is the top-down priority set, as laid down by the firm's executives about what activities it seeks to pursue, and how they should be pursued. This study recommends four key actions.

29.3.2.1 A service-strategy

This whole section is predicated on an organisational effort to adjust its makeup to be more service-aligned. This is, in fact, the fundamental action to help move a firm in this direction – actually making service awareness & capability a corporate priority. This means communicating from the executive level, all the way through to unit managers, that the firm is seeking to become more than a manufacturer.

Embedded in such a strategy is a strategic logic – much like the core reasoning put forward in this study – that helps guide managers in decision making. This requires fashioning an internal narrative that explains *why* pursuing a service-aware approach is necessary for the firm's prospects.

29.3.2.2 Business planning

Establishing robust business plans for a prospective service program is an important capability for a service-aware firm. This includes being able to cost a proposed service program properly, and understand the factors up-front that will drive the customer's imperative in the near-term.

There's also an implication for the product divisions and units within the firm. If the firm's products are to be the basis of a Complex Integrated Solution (as a product-service system), there also needs to be effective business scenario planning with regards to the product support resourcing that may be required. Ensuring that it's part of a 'one company' approach to providing a Solution, this may require substantial business plan development between a product division, and a service one.

29.3.2.3 New service capabilities

Any serious strategy to become service-aware needs to invest in service capabilities. It's a nebulous term that can refer to many things but may take the form of a centre of service excellence for training and development in service design for the firm. It can also offer a useful focal resource point for experimentation, research, service methods (including the above business planning) and learning from other programs. This is developed a little more under creating a professional 'home' shortly.

29.3.2.4 Service offering

Recognising at the strategic level that services are an important offering of the company, and as such, the firm will be engaging in many business activity typologies is an important revelation. This strategic realisation then feeds into governance structures and organisational design to provide allowances for variations in these activity types.

29.3.3 Organisational design

The second key facet is that of organisational *design* – not just structure. It involves the key organising principles for the firm and relates to the strategy the firm is pursuing. It involves the reporting structure, but other aspects too, such as key business processes, and support capabilities and infrastructure.

The field of organisational design is one that is a thesis in itself, and in reality, all these four facets are part of an organisational design approach. However, it's worthwhile placing here as one of the four facets, and whilst seeking to become a service-aware firm requires rethinking the firm's organisational design in far more detail, the following few recommendations here may start such a thinking process.

29.3.3.1 Developing an internal service school-of-thought

Given that products are visible, and services generally not, making service capabilities visible is important. There are other ways of doing this, discussed shortly, but creating an internal way of 'doing service' is an important step to take to solidify Complex Service Programs as a primary part of the firm's landscape.

This includes features such as:

- Building the firm's management approach for Solutions, including key management frameworks (discussed shortly)
- Establishing a common service-orientated language across the firm
- Identifying and communicating the firm's unique competitive edge when it comes to Solutions (based on what it does well)
- Establishing a training regime to explain the key service principles and models the firm chooses to work by.

29.3.3.2 Recasting important Functions

Helping remove conventional 'blinkers' from existing enabler functions, such as engineering, will help keep the firm competitive in its various typology offerings, including Solutions. The work presented in Part IV of this study is a major piece that can help aerospace & defence firms recalibrate these important functions to be more commercially aware, and also be more service-aware. Such 'recalibration' efforts can be delivered both at a training level with function staff, but also at the team scope and design level.

29.3.3.3 A professional services identity

One other way of increasing visibility of services is by highlighting various service roles with uniquely identifiable descriptions.

Some conventional terms, such as Project Manager or Business Development Manager, are not entirely suitable for a Complex Service Program typology, given the ongoing nature of such activities. Instead, new titles, such as Solution Architects, Solution Directors, Solution Managers, or Solution Development Managers will help bring a unique focus to a style of activity that is beyond the normal manufacturing paradigm. It also connects with an individual's sense of professional identity and establishes a narrative about their role being unique from such traditional paradigms.

29.3.3.4 Reframing existing product-centric departments

Traditional frontline activities for a manufacturer, such as production, may need to take a 'capability-as-an-internal-service' approach. For example, a production line might be centralised internally under a manufacturing provider function that produces equipment as a 'supplier' to an internal product customer (e.g., the traditional widebody Boeing products are produced by the one production organisation at Everett, rather than being 'owned' by the product programs or business units).

Rather than see services as 'enabler's' or 'bolt-on' additions, these traditional production functions may be worthwhile being reframed as one (of many) important business activity typologies. Production might be a typology that operates in a 'direct-to-the-customer' mode, but which might also just be part of a broader firm effort to integrate with other product or service elements (that is, a product unit that is delivering to an internal customer).

This gives rise to the recommendation of recasting such product business units as product ecosystems – epicentres of technical effort around a product, but which are not merely providing a volume-based production line, but rather find are deployed in various ways, from production order delivery, to product support, to new business creation and adaptation.

It's an important distinction, especially given that this conglomerate approach is less a set of hardened product and service lines, but rather a network of ecosystems that connect with each other in less than predictable or linear ways.

29.3.3.5 Creating product ecosystem plans

It then follows that, especially for capital assets, systems or products, developing a product ecosystem planning process would make managing this network perhaps a little easier.

A product ecosystem plan is proposed to be a repetitious planning process that scans for stakeholders who may have some vested interest in the product or system, and what their potential needs might be, and how the product organisation can structure itself to respond. These may include:

- Other units across the company want to learn from it, integrate it, or develop it into something else
- Regulators and standard-setting agencies want to ensure it meets standards
- Customers want to buy the device/system, etc. – but want to access more than just 'the box.' They want support, training, or other intellectual engagement on the product or system.

Such an approach helps signal a move away from the idea of suppliers and customers of products, and instead become multifaceted units that reflect the broader corporate structure. Of course, not all interactions can be predicted, but the process of planning for major interactions can help prepare such business units for unexpected developments.

This approach is also helpful in establishing a service-centric product governance approach. It's also a useful approach for producing an adequate business plan for the product business unit, including resourcing for post-production efforts, as well as a management review regime to periodically assess the health and capability of the product business unit to meet the needs of the broader product ecosystem.

29.3.4 Cultural & performance leadership

In addition to the corporate strategy which sets the direction of the company, there's need for leadership from company executives to affirm certain behaviours by establishing certain cultural elements.

29.3.4.1 New ways of measuring success

Across the firm, there needs to be a more open-minded approach to measuring program and contract success. The product-centric 'price-schedule-quality' paradigm must be enlarged. Instead, at senior management meetings, other key metrics should also be encouraged, discussed and/or expected. These include availability, reliability, flexibility, order fulfilment rate, customer experience rating, adaptability, and flexibility.

In addition, executives should expect to operate service programs on more than numerical result data. This includes a deliberate approach to gauging customer feedback and understanding how the customer is experiencing service programs (either by themselves, or by competitors), and use these insights to manage the program according to the narrative that emerges, and not just the headline results.

29.3.4.2 Develop a discipline 'home' for service professionals

Given that the traditional activities of aerospace & defence firms are quite well engrained in the culture of such firms, there's a need to create greater visibility of service-based disciplines, such as solution architects, service designers, maintenance planners, fleet managers and in-service engineering staff. Establishing a clear professional 'home' within such a firm is a way of making such professionals feel like they have an important role to play in the company, and can draw on the development and support of a central support structure.

This might be served by introducing three key aspects to such a home:

- Establishing the 'C-Suite' role of a Chief Service Officer (or another high-profile individual) to champion service-focused roles and disciplines.
- Establishing a Service Excellence Training centre – to run courses, share experiences and challenge staff and leaders to examine how service concepts apply to their business. This might include courses on becoming customer advocates.
- Training and awareness programs – in addition to the excellence centre, is a program to expose firm staff to service environments that they're perhaps not used to. This might include customer advocacy exchanges (i.e., working in a customer organisation), and customer service training.

Establishing a course of the Complex Service Program/CIS typology would also be a useful step, and would incorporate the logic and thinking styles relating to Solutions from experience and research, such as this study. In particular, it would draw attention to the important nuances between product and service-centric thought, including:

- That Solutions are built around customer organisations, and more specifically, their imperatives
- That Solutions are for organic in nature, rather than mechanistic
- That identifying the customer, with their complex political structure, requires unique attention.

29.3.4.3 Career pathways & rewards

Leading on from this concept of a professional home is building a culture where "post production" activities are not seen as career-ending or 'punishment,' but rather a highly prized posting for an employee. This can be done in several ways, including:

- Publishing a career ladder in the service stream, including promotion opportunities in a Solution environment (e.g., moving from being a maintenance planner, to being a service designer, to being a Solution director)
- Building clear career development pathways across the company that place a prerequisite on experiences found in the services stream. This might include 'customer advocacy' experience or delivery operations experience (to understand the steady-state nature that a customer is seeking on an ongoing basis).

29.3.5 Governance structures

29.3.5.1 Business management policy suite

This where the 'rubber hits the road' – where actual tactical interventions via management frameworks in the company's Business Management and Process Frameworks can be enacted. Thus, it's where this study's findings are best deployed.

Existing 'one-sized-fits-all-activities' approaches to business management systems need to be rethought in a firm that operates across a wide-range of business activity typologies. A starting point would be to identify contracts or customer offerings as being one of even just three business activity typologies – product, transactional service, and complex service. The Service Program Spectrums model in Chapter 4 might help with this. The firm then may seek to establish more specific management systems around these different typologies.

A business management system for a Complex Service Program typology then includes:

- Creating a Solution Development Strategy and a Solution Management Framework for each contract
- A mandated management review system that incorporates the three horizon model, as well as a self-assessment of service posture
- A 'lifecycle' model that is based on the segment-cycle approach, outlined in Chapter 24.

29.4 An actual management methodology?

It must be noted before pressing on that this implementation framework is created in the context of 'traditional aerospace manufacturer' firms. Of course, as discussed in Chapter 3, there are other providers of Solutions. How they deploy this study's insights might be a different path.

The question must also be posed – does this implementation framework constitute an actual management methodology?

In short, no. What it does do, however, is provide the means for activating the insights and findings of this study, particularly into a 'traditional manufacturing' firm. However, as is discussed in the next chapter, there's another important step to take.

CHAPTER 30

Towards a New Management Methodology

Concluding Thoughts

30.0 Has progress been made?

After embarking on this journey to seek out new insights and ideas to fashion a management methodology for Solutions, it’s important to ask an important question: ‘are we there yet’?

30.1 What this study doesn’t cover

Before answering that question, it’s important to reflect on some of the aspects this study has not covered that might have been expected as part of the above question.

There are several factors that have not been studied, but are worthy of further investigation. They include:

- A more thorough implementation and organisational transformation approach
- A process, methodology or means to bring disparate parts of an enterprise (or partners from across several enterprises) together to establish Solutions
- An actual business planning process for Solutions (including cost modelling)
- Understanding ‘imperatives’ more. This isn’t just performance specification of systems, but also understanding customer business models, bottlenecks, power structures, and other undocumented expectations. In other words, learning to appreciate the world of the customer.

30.2 Is it even necessary?

An even deeper question is whether this study has been worthwhile at all? This study has gone to some lengths to present insights and conceptualisations to help aerospace & defence practitioners and executives to break free from the clutches of product-centric thought.

But is it all that bad a school of thought?

It has its advantages. Many product development engineers may never have a conversation with those who utilise the versatility their efforts ultimately yields, and thinking in far more product-centric, and 'distant' means is actually a mentally efficient approach. But this is perhaps core to product-centric thought – that problems are best solved in isolation from the customer (except via controlled interfaces that can stymie or inadequately capture instead of accentuate the effectiveness of such interaction), and thus should be solved in the most efficient means possible. This results in means standardising a response (as expressed by Vargo & Lusch [233]).

It's an approach that's ideal for some classes of problems (e.g., producing a cost-effective device that meets a broad need), but not all problems. As this study has maintained, it's not an advantageous worldview with which to try and build and manage sustainment-focused Solutions.

30.3 Willy Wonka revisited

So, has this study produced a comprehensive management methodology for sustainment-focused Complex Integrated Solutions that might alleviate another Willy Wonka tending to the vegetable garden situation?

In short, the answer is no. There are two reasons why.

First, there are other areas and ideas that can help refine the core reasoning and ideas presented in this study that will help build a richer picture of Solutions. This study is not the sole source of wisdom on the topic.

But second, and more importantly, a management methodology relies on the individual practitioners to build their own mental models which then translate into effective management techniques and approaches for managing Solutions. This study has helped feed a core-reasoning about Solutions, as well as the role that engineering plays, but ultimately it comes down to individuals in their own contexts to apply these ideas in a meaningful way.

It's important because a thoroughly powerful methodology cannot be produced for Solutions for one simple reason. The very definition of a Solution is that it is unique; a one-off, customised to a particular context and need. It's the very antithesis of 'one size fits all'. The sheer understanding that such Complex Service Programs require cannot be a one-size-fits-all, and thus practitioners and executives must actively seek out their own mental models to devise the most suitable way of managing such a Solution operation.

30.4 This study's quest

What this study has sought to do is find meaningful ideas that are executable – even if not immediately implementable – that helps play out this central school-of-thought in the aerospace sustainment Solutions context.

The models and frameworks posed in this piece will likely be helpful to practitioners in their quest to mould a management methodology and routine for their unique circumstances. Indeed, this whole piece has been about stimulating and promoting practitioners, managers and executives to construct their own deeper and richer mental models and to consider their understanding and conceptual blind spots. Just awareness of the alternatives to better structure and organise such service programs will help such professionals build a level of cogency that leads to building momentum and rhythm (or, as this study has referred to it, 'steady-state operations').

30.5 A departing thought

This study has also been about rethinking about engineering, especially in the in-service environment. Engineering is so much more than 'making things'. The true value of the profession is found in the *effect* engineering units can invoke (or the ensuring of something), and not just the things they produce. Depending on how they're organised, and the mode they're deployed in, engineering units can affect safety, societal, customer and commercial outcomes, and leaving one's worldview unenlightened to this fact does a disservice to the profession, and to those the engineering profession serves.

There's something else that this study leaves. A rationale for rethinking and recasting engineering as more than a collective brains-trust in a Solution environment; rather, it can be something far more aligned to helping meet business needs, without compromising on safety. It's a tale of an outfit that has moved from a sole focus on the technical, to being concerned with producing effects that meets its customer's needs.

It's a movement from spanners, to suits.

Appendices

APPENDIX A

The Milvus Type Design Group

Overview

The DefTech Global, headquartered in Essenheim, not only provides the through-life trainer capability solution (through its local subsidiary), but also is the manufacturer of the Milvus aircraft itself. As the Original Equipment Manufacturer, the company is recognised under Essenheim Defence regulations, as a *Type Design Group.* This TDG status, much like Part 21J of the EASA regulations, grants rights to the organisation to undertake aircraft design and bestows certain privileges in the certification of any aeronautical product. Because this company has obtained this status, it assumes the role of the Type Design Group for providing engineering design support services. It is the holder of the Type record (the data-sets concerning the definition, configuration, and historical description of the aircraft), however, under Essenheim Defence regulations, the actual holder of the Military Type Certificate must be a Civil Servant (Government employee), and thus tends to be held within the associated project office.

The parent company is divided up into a number of substantial businesses. The TDG status is held within the Military Aircraft Division, which in turn is made up of a number of other aircraft programs. Most of the programs are coordinated out of a large facility on the West coast of Essenheim; however, the Milvus is built and managed from a facility on the east-coast. More is discussed on this shortly.

The relationship to the Type Design Group

The SDG has a unique relationship with the Type Design Group, insofar as the TDG is both a supplier of services to the SDG, and is a key part of the Design Support Network, but also the TDG extends its product-assurance governance framework to the SDG as it forms part of the global organisation. In other words, from a business perspective, the SDG is the master, but in terms of a number of fundamental safety-related matters, the SDG is subservient to the TDG. However, the SDG's Engineering Unit is still the primary integrator of engineering support for the fleet, and thus must review any input from the Type Design Group, although incorporation of Special Instructions and other advice is virtually always adopted.

As the original equipment designer and manufacturer, the Type Design Group is recognised for its level of insight to the aircraft design and its engineering competence. Thus, for instances where a change to the aircraft design is beyond the scope of the SDG's own engineering Authority, it will refer to its Design Support Network to develop the required change. The majority of these instances are handled by the Type Design Group, although it is not the Type Design Group for the engine. They are related to and managed under similar procedural arrangements.

Origins & history of the Type Design Group

It is difficult to discuss the Type Design Group in isolation from the life of the Milvus aircraft. Indeed, the very life of a Type Design Group is directly tied to the lifecycle of the aircraft type, as it is the mandated organisation responsible for the ongoing management of the aircraft type until the last aircraft is withdrawn from service[49]. However, it is also important to note that it is not the project-management organisation of the Milvus, but rather the specifically defined organisation responsible for the technical management and integrity of the aircraft. Other business units exist within the Military Aircraft division to provide certain functions, including the logistics management of spares, and other program management functions such as finance, business development, and contract management, although in this case the Type Design Group is deeply involved in many of these facets as well.

The origins of jet trainer aircraft in question go back to the 1960s when the Essenheim Air Force expressed the need for a replacement jet-fighter trainer aircraft. The requirement included an agile subsonic trainer with lower maintenance costs, a relative ease-of-handling (although with a sufficient level of challenging parameters so students could grow their flying skills), and because of the training need, be a tandem two-seat design. After earning the design contract, DefTech Global developed a prototype that first flew in the early 1970s.

The company that designed & built the aircraft was taken over by the forerunner to the current global aerospace and defence company that is the subject of analysis. The two firms had different philosophies and approaches to designing aircraft. The firm that designed the original aircraft were known for their agile, dynamic and 'cheerful' approach to aircraft design, sometimes at the expense of properly documenting all the design and manufacturing aspects of the aircraft. This was in contrast to the other firm (who brought the first firm), where there was a strong emphasis on procedure, control and discipline. The acquisition of the firm was completed in the late 1970s. Shortly thereafter, the production and engineering facility locations also changed. In the 1980s, the manufacturing line for the aircraft was moved to its current location from the southern part of Essenheim. In addition, the engineering team was moved, culminating in the engineering and manufacturing operations been co-located for the first time.

Since the first aircraft of the type flew, there have been a number developments and derivatives of the aircraft type. In all, over 11 variants of the aircraft have been developed so far, with a global fleet of over 900 aircraft in over 15 countries. Whilst the general shape of the aircraft has been maintained through each of these designs, there have been considerable changes between the very first model, and the most recent model that is available. Some of the key derivative designs include a naval version that

[49] In the civilian environment a TC can be transferred to another entity, and under certain circumstances, can be operated without there even been a TCH (such as re-classifying the aircraft as Experimental).

is used as trainer for carrier-based aircraft complete with arrestor hook, a one-seat light attack/multi-role fighter, and a series of versions for other nations that embodied specific updates and systems for their requirements. Some of these changes were items like new engines, but in some instances involved a new wing design, itself requiring major structural rework to the aircraft design for incorporation.

However, as the aircraft's original design pedigree is quietly edging towards the better part of 50 years, and combined with the global downturn affecting defence budgets, the days of the aircraft's continued production look numbered. Whilst a series of large contracts were placed in the last 10 years, these aircraft have either been delivered to their customer, or that the final assembly of the aircraft is taking place in-country of the customer organisation. This factor plays into some unique factors associated with the current site that the Type Design Group currently occupies, following the 1980s move. Apart from some piece-meal use of testing on-site facilities, this venue is almost entirely devoted to the design, manufacturing and in-service engineering support of the trainer jet aircraft. It is this unique characteristic that makes this case a critical one – it isolates and amplifies the management considerations for the program. On-site numbers have fluctuated substantially over-time too as a result of the above factors. Once there were in excess of several thousand staff at the site; recent numbers have been around the 1300 mark.

Key roles of the Type Design Group

To understand the role of the Type Design Group, it's important to clarify the difference between the verb and the noun of *design*. The Type Design Group does not just undertake the dynamic activity of designing new products, but is responsible for the fixed (albeit not always static) design of an aircraft type. The "design" is much like a blueprint, a picture, or model of what the intended aircraft state is; the purpose of manufacturing processes and systems, maintenance instructions, and the maintenance activity itself is to uphold actual aircraft to that standard of design through-out all phases of the product lifecycle. This includes ensuring that the manufactured aircraft conforms to the specified and approved design, and that all maintenance actions restore the aircraft to this standard as well. It forms a key foundation in the delivery of safe aircraft, an issue touched on later.

Despite the soon-to-be winding up of production, there is still both a strong need, as well as regulatory mandated need, for the Type Design Group. In recent years, its key roles have been to:

- Design and coordinate the development of new aircraft models based on the existing aircraft type
- Provide business development support
- Provide support to the production operation, to define the build standard acceptable, and resolve emergent technical issues, such as deviations and concessions
- Provide engineering support to the production flight-test group
- Provide in-service engineering support to customer-operators and field-service representatives

As described above, the design and development function is the taking of requirements from a customer and devising a new derivative of the aircraft type, evolving the Milvus' pedigree. This can involve anything from a minor adjustment to the design, such as incorporating new sensors, to more substantial items such as new engines, to a complete and extensive redesign of the aircraft, including major structural items. For instance, a marketing briefing by the company claims that the only original components left from the original aircraft design compared to the current derivative model is the canopy, and the speed-brake structure. Evolutions on the design have been quite common, however. For instance, the first cadre of aircraft delivered to the original Essenheim Air Force customer, once put into service, were not exactly what the operator was after. A minor redesign of the aircraft saw the second model released shortly thereafter, which expanded the aircraft's weapons capability. The fleet of original model aircraft were then upgraded to the standard of this second model.

This particular line of work relates well in the business development focus of the TDG. Whilst not a product governance function, and thus not defined under any regulations, the TDG still provides the centralised focus around the aircraft and thus has a de facto business development thrust to its operations. Whilst not the sole business development function within the company or the division, it helps develop proposals that are presented to potential customers, including the provision of cost information, estimates for the incorporation of new systems to offer an enhanced aircraft model, as well as for providing information on through-life support contracting proposals.

In this instance, the Type Design Group is also responsible for providing the engineering support to manufacturing operations[50]. The TDG provides support in forms including configuration management, manufacturing defect investigation and deviation/concession management. As each aircraft is built, the production system is to ensure that the aircraft is built to the correct standard, that the final product conforms to the original drawings, specifications and other design data. There are some instances where new processes need to be developed (such as in the case of new updated models of the aircraft type, or modifications). There are also clarifications that need to be issued to manufacturing staff about the design data and standards required as they arise. In addition, any defects or non-conformances that are found during the manufacturing process must be investigated, both to determine the cause, but also to assess as whether a repair can be devised, the item can be used without modification, or the item be scrapped. These efforts are undertaken by the engineering team, with decisions and communications tracked. In the instance of deviations and non-conformances, these are recorded against that particular aircraft type. The level of effort devoted to manufacturing by the TDG fluctuates with the projects, sales and circumstances at the time, but at a peak, the design and manufacturing role took up about 90% of the time of the TDG. This figure has been changing significantly in recent years.

The TDG also provides a level of engineering support to the Flight Test Group within the company. This group is based on the west-coast of the Essenheim, and coordinates and undertakes both production test-flights as well as development and special flight tests. Production test-flights occur after the production of each individual aircraft to verify its build quality and flying characteristics to ensure the quality of the product and ensure there are no manufacturing deficiencies prior to handing the aircraft over to the customer. Prior to handover, the group coordinates for the customer operator to undertake their own test-flight prior to taking delivery of the aircraft. Development and special test-flights are non-production test-flights, where certain characteristics are been tested for a number of reasons, including the development of a new model of the aircraft type, the incorporation of a new system, or to investigate an issue with the aircraft. Whilst this group is separate from the Type Design Group in terms of reporting lines and structure within the company, there exists a close working relationship. When required, the Flight Test Group will call on the TDG to provide support in a number of forms, including answering queries, through to join taskings on an issue.

[50] The structure used for engineering support to manufacturing depends on the company, product/program, and even site. Often there will be dedicated engineering teams purely for manufacturing; in this instance, because of the size of the aircraft production capacity, the engineering team is part of the Type Design Group, which undertakes almost all engineering activity for the Milvus.

The major focus for this research is on the line of service that pertains to in-service support engineering. In recent years, this has become a larger part of business for the Type Design Group as production thins out – once support engineering was about 10% of the TDG's effort, but now is moving towards an almost exclusively support-focused operation. The in-service support activities pertain to a number of customers, each with different requirements and each requiring different levels and depth of support – some customers undertake almost all their in-service engineering in-country without the company's assistance, whereas some are entirely reliant on the TDG. The SDG in this case study is reasonably-to-very reliant on the TDG, although it would not be classed as extensive.

The major lines of delivery of in-service support engineering fall along the following lines:

- Technical queries
- Fault investigations
- Technical instructions
- Technical queries
- Structural integrity management support
- Training needs analysis
- Modifications
- Survey & quote for major items, including upgrades
- Minor and major repair scheme development
- Accident & incident investigations

Other forms of support are provided by other functions across the business division and delivered through the program management organisation, including:

- Flight test engineering & operations
- Spare-parts supply

These specific lines of delivery are discussed in greater detail both in this section shortly, and are shown in context under SDG operations.

Organisational profile of the Type Design Group

In order to deliver on these key areas, the organisation is made up of a number of functions, and is coordinated through a matrix-style structure. The structure changes somewhat regularly to adapt to changes happening within the program – for example, a major contract win will have resources moved and structured around it, and as the activity subsides, it is subsumed back into a more 'business as usual' structure.

The TDG product governance structure is shown in Figure 102. The Type Design Group is headed up by the Engineering Director who is also the Chief Engineer for the Milvus and its associated systems. Reporting to the Engineering Director are delegated authorities for key aspects of the aircraft system, including:

- Flight Systems
- Software

- Structures
- Aerodynamics
- Mission Systems
- Flight Test Instrumentation
- Design

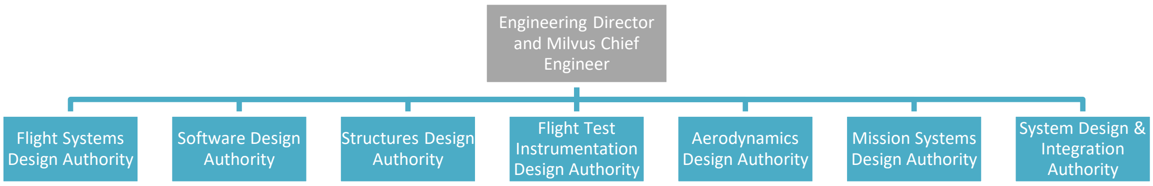

Figure 102: Milvus product governance structure

Each of these delegated authorities possess the knowledge and competence to provide an acceptable oversight and stewardship for the trainer aircraft design, with responsibility for those key functional areas made clear. Each of these areas also have a team of engineers who are tasked with various work packages for the approval of the delegated authority. However, whilst this structure clearly shows lines of delegated authority, it does not clearly articulate some of the greater complexities of the Type Design Group, nor does it convey a fuller sense of the responsibilities and functions that it discharges. Presenting this in a simple snapshot is not straight-forward.

What is also not reflected through the structures shown thus far are the key discipline areas broken down into more detail, nor does it show some of the other support functions that are necessary. Whilst not fully aligned with the governance structure shown above, the functional breakdown of the Type Design Group discipline and capabilities areas include:

- Weapon System Integration
- Mission Systems
- Airframe
- Test & Evaluation
- Airworthiness
- Quality Assurance

- Publications
- R&D
- Training Systems
- Production Support
- In-Service Support

In addition to these key areas are the following 4 functions that are either a part of, or connected to, the Type Design Group:

- Modifications management
- Spares & Logistics
- Flight Test Group

Each of these areas is described in the following sub-sections. There are two important things to note. Firstly, these are sub-functions or attributes that are grouped under key functional areas, rather than how the organisational structure exists. These are not teams that report to a functional leader; they are simply the types of functions that are required within the TDG. The exact structure, size, reporting scheme and responsibilities vary from time-to-time, depending on the 'season' that the Type Design Group is in. Second, these areas were identified in an internal document at a time when new design, production and support activities happened concurrently, and thus should be read as such.

A closer look at some of the key roles

Weapon System Integration Function

This function is responsible for the various integration functions that are required to develop an effective aircraft. Something that was found through the years of designing new models of the aircraft type was that whilst the key discipline areas were well represented, there was no strong integration activity between them. Responsibilities that didn't just lie with one area were getting overlooked or poorly managed. Hence, the integration function was established.

To aid the integration of the aircraft, the function is made up of the following attributes:

- Engineering management
- Support engineering (reliability, maintainability, testability)
- New business
- Flight operations advisors
- Ground support systems
- Configuration management
- Systems safety
- Requirements and certifications
- Ground support equipment

Many of these functions are not strict designing activities, but constitute good project management and product governance disciplines. For instance, Engineering Management refers to the coordination of engineering resources, planning, scheduling and reviewing, much akin to project management, but at the technical level. The New Business attribute helps assemble bids using the technical and operational knowledge (including cost data) available in the TDG. Flight operations advisors assist with flight test activities and the training of customer air-crews. The development and integration of ground-based planning, review and monitoring systems for the aircraft falls under the ground support systems attribute, and the design and development of ground-based support equipment, including testing systems, interface ports, and other assembly's come under the notion of ground support equipment (GSE).

There are some other attributes which deserve special attention. Support engineering, not to be confused with the in-service support engineering that has been the focus of this thesis, relates to the analysis of the aircraft design from the perspectives of reliability, maintainability and testability. Techniques including reliability analysis, and logistic support analysis (LSA) are applied to devise the RAMS profile of the aircraft, something that is used in the devising of the maintenance plan and associated documentation (something that also falls under this attribute).

System safety builds on the support engineering attribute, in conjunction with the Airworthiness function. It is the process of analysing the aircraft design (at the point of design) for potential hazards, and rectifying these prior to delivery to the customer (a significant part of the certification process). The requirements and certification attribute is the taking of requirements, including mission, performance, safety and economic factors, and through the engineering management function, design an aircraft that meets those requirements. The successful meeting of these requirements permits the aircraft to be certified[51].

Airworthiness function

The Airworthiness function operates across the other TDG functions in what might be described as a safety-integration role. It also spans both the initial certification of the aircraft, and in-service airworthiness management from a Type Design Group perspective. However, whilst it is all-encompassing from a safety perspective, the airworthiness function has a level of independence from the project and engineering aspects of the TDG organisation. It does not undertake engineering work, but communicates the airworthiness requirements for design tasks, and acts as an airworthiness advocate through-out the TDG organisation. It also undertakes audits and oversight of the TDG to ensure that appropriate airworthiness-related processes and standards are followed. In addition, it does not control the airworthiness of customer fleets – this is the responsibility of customer organisations, including the SDG (even though it is part of the same global company) – but rather acts as the coordination point for in-service airworthiness matters. To protect this independence, the Airworthiness function reports directly to the Chief Airworthiness Engineer in the company, rather than to the Chief Engineer of the Milvus.

Under the initial airworthiness certification regime, the function is responsible for oversight of the airworthiness-related processes used across the TDG, tasks the various functions with airworthiness-related tasks (especially hazard analysis), and communicating the design standards that are to be followed for both original aircraft design, new model development based on the type design, and design-changes to the aircraft, such as modifications. It is also responsible for assembling the safety-case for the aircraft – in effect a sustained argument that the aircraft design is safe, complies with relevant airworthiness requirements, and that identified hazards have been assessed and managed. It also

[51] certification in the civil context only means complies with safety regulations; in the military context, it can also mean that it meets operational, mission and role requirements too

coordinates the certification process with the appropriate areas within customer organisations for the certification and formal acceptance of the aircraft type (from a certification and airworthiness perspective).

The in-service airworthiness capability is generally concerned with two key activities – defect/fault investigations and technical instructions. The investigations activity in effect looks at more than just defect or fault investigations, but everything from isolated technical faults, through to incidents and accidents of both a technical or operational nature (i.e., an incident or accident that has been triggered by technical problems, as opposed to an event caused by pilot error or some other sought of operational factor). Fault, incident or accident arising's are considered across the full spectrum of product management, including manufacture, ground-test, flight-test, servicing and maintenance, and normal flight operations.

This investigation activity involves the gathering of information from an event, including coordinating or conducting the necessary inspections, and reporting on findings. The Airworthiness function have set techniques for investigating different events, from conducting fault investigations, right through to been called out to a crash site where many protocols and hazards, such as unexploded ordinance, must be respected. For a serious incident or accident, representatives from the Airworthiness function may be called on as experts by a customer's own investigative service or process, such as a Board of Inquiry.

The ultimate aim of an investigation is to determine the cause of an event, and the devise corrective actions to prevent reoccurrence. These corrective actions can take a number of forms, including:

- A change to maintenance servicing requirements and procedures
- A change to the permissible operating parameters (e.g., use of systems, conducting certain manoeuvres, or operation in certain environmental conditions) through imposing temporary operating limitations, or a permanent change to operating procedures (both a process managed through the technical publications unit)
- A requirement for the inspection of components, systems or other items that are currently in-service
- Instructions for the modification or replacement for current equipment

Many of these actions are delivered through official instruments known as Special Instructions. These instructions are for urgent, generally temporary action to remove or control faults which affect the flight safety of aircraft. They also allow the aircraft to continue flying safely pending a permanent solution to the fault, generally a modification of some sort. There are three main types:

- Special Technical Instructions (STI) – one-off packages of work or actions within a specified period to isolate and repair or present a potential fault with the aircraft. They are similar to an airworthiness directive (AD) under the civilian airworthiness regime.
- Servicing Instruction (SI) – very similar to an STI, albeit that it is a repetitive action
- Special Flying Instruction (SFI) – a notice issued to inform aircrew of temporary changes to normal operating procedures.

Whilst it is normal that the outcome of an investigation, whether it is in progress, or has concluded, is the issuing of one of these instructions, there are times these are not enough, and the Airworthiness function can recommend the grounding of fleet to a customer if it believes there is a potentially immediate and critical issue with the inherent integrity of an aircraft or fleet. Often a grounding will be followed by the devising and issuing of temporary instruction that allows the aircraft or fleet to fly again;

however, only until it can be proven that the aircraft can operate safely with such temporary fixes can an aircraft or fleet return to operations.

As a side note, these official instruments draw attention to the actual power and authority of the TDG in the jurisdictions that it involved in. Each of the above instruments are recognised as mandatory by the Essenheim-based customer, as the TDG also acts as the engineering authority for the aircraft fleet in that country. However, for export (i.e., non-Essenheim operating nations), these instruments have no legal effect, unless that nation's customer imposes on itself that such DA-issued instructions are mandatory.

One final facet of the Airworthiness function is that of providing design improvement feedback. Figure 103 shows how the two aspects of the Airworthiness function – initial certification, and in-service airworthiness – both provide a return to the process of designing and improving the aircraft. On the initial certification side, issues through-out the development process are tracked, including testing reports, problem notes during development, design reviews, inspection results, and concessions and deviations from the approved design form part of a picture of the inherent nature of the design. These problems that emerge, and are rectified or managed prior to certification, can help improve the methods, standards, procedures and experience of the Type Design Group, to help them continuously increase their knowledge and capability by learning from instances where events did not happen as expected (e.g., the failure of a component during a given test). This feedback is then enhanced with 'live' operational information about how the aircraft has performed in the field – what systems work well, and what aspects of the design could be improved. The combination of these sources of feedback and information enable the TDG to improve both the product, as well as its own inherent technical capability as an organisation.

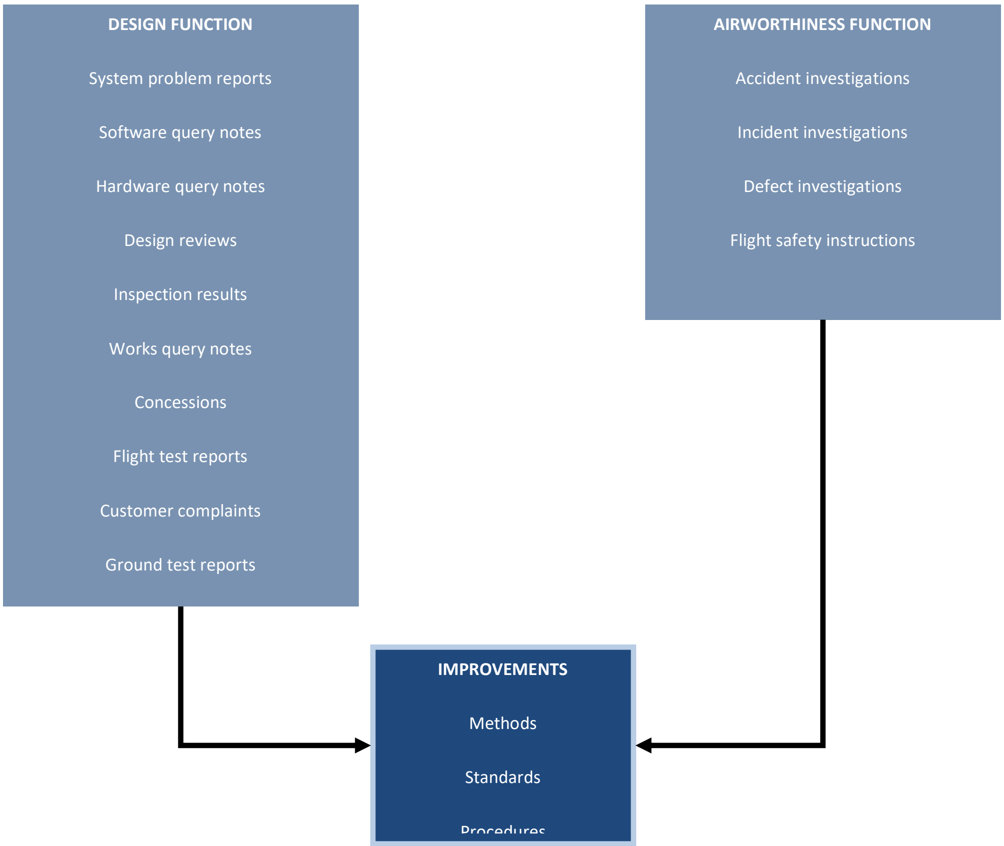

Figure 103: Design improvement feedback loop for the Milvus TDG

Publications Function

The Technical Publications Function is responsible for producing the vast number of aircraft-related publications used by customers. The full suite of publications, not defined here for space reasons, includes items such as:

- Flight operations manuals
- Air-crew training manuals
- Maintenance planning data
- Maintenance task procedure manuals
- Repair manuals and specifications
- System-specific description and maintenance publications (often from other vendors)
- Maintenance training manuals

The Technical Publications Function's responsibilities include:

- Controlling the full suite of publications that define the aircraft's safe operating parameters and instructions for the continued safe operation of the aircraft
- Responding to requests for improvement, or to the release of new data that impacts on the quality of authoritative information about the aircraft, its operation, and support

- The timely communication and distribution of the appropriate technical publications to customers

The management of these publications is a critical task, as they form the single source of absolute truth concerning the operation and sustainment of the aircraft. Unauthorised deviation from the information and procedures in the manuals voids any warranty on the aircraft, and personnel could be personally liable. The publications suite form part of the actual aircraft design (the blueprints that define the aircraft), and are part of the certification process of the aircraft, including the final type certificate for the aircraft. In effect, these technical publications are the given assurances by the aircraft TDG that, if followed by trained and competent personnel, the aircraft will experience safe flight. An added complication is that each customer has different requirements for publications, such as format and mode of delivery, and also that customers operate different models of the aircraft type, meaning that there is not just one suite of publications that covers the entire aircraft type – even minor variations can cause substantial issues if not properly identified and managed. Hence, there is a significant responsibility on the Technical Publications function to ensure the accuracy, quality, control and timeliness of such documentation.

Additional functions

In addition to the functions described above, the Type Design Group also has responsibilities that fall along the following lines:

- **Quality Assurance:** Conducts an audit program on internal processes as well as supplier quality and is focused on assuring a quality output of engineering and design services into the TDG.
- **R&D:** Coordinates the development, and more particularly, adoption of new technologies and processes for future aircraft models or for retrofits.
- **Training Systems:** Responsible for the design, oversight of manufacture, and provision of technical support for training devices associated with the aircraft type. This includes simulators, ground-based training aids, and maintenance training products. In some jurisdictions, this could be a Design Approval Holder of its own; in this context, however, it falls under the scope of the Milvus TDG.
- **Production Support:** the Type Design Group provides engineering support to the production organisation that actually builds the aircraft.

Modifications Management Function

There are a number of instances where a modification is required to an aircraft, and it is the role of the modifications management function to manage the process. It forms one of the critical support lines of delivery to the SDG, and ultimately the customer organisation.

The modifications team is made up of a Technical Project Engineer, a Vendor Modifications Administrator, a general Administrator, and the Modifications Manager. This team reports directly to the In-Service Engineering Manager for the aircraft type.

The TDG has a detailed procedure for the management of modifications for each customer, as each one has differing needs, their own internal processes and systems to comply with, and financial arrangements. However, the main steps to the process are:

- Customer request or identified need
- Investigation and review and scoping of modification requirement
- Raise formal project documentation, configuration management control & obtain funding and approval
- Undertake modification engineering work
- Prepare manufacturing (if required)
- Assemble mod kits/embodiment approach
- Raise acceptance documentation
- Modification close-off

The need for a modification will normally be raised directly by a customer organisation, or for some internal company reason. A customer request could be for a number of reasons – from adding new capabilities or systems, to dealing with an obsolescence issue, through to a dealing with a reliability issue with a component. Similarly, the company may also raise a modification for the last of those two reasons, or to rectify a deficiency or warranty issue with the aircraft. Determining the actual need is important, as the current business model is to charge the customer for modification taskings, except where the company is undertaking the modification because they were at fault and are rectifying an issue.

In-service support & role of the customer desks

As previously mentioned, the organisation possesses a matrix structure – this is in the form of taskings from production, and in-service support needs from operators. A subgroup of the overall Type Design Group is the Support Engineering Group for International customers and is shown in Figure 104 (the domestic Essenheim customer is yet another entry-point into the organisation). The purpose of the group is to be the focal for each operator customer into the Type Design Group, to coordinate and integrated tasks, and to act as the advocate for their customer. With over 15 customers of varying sizes, needs, expectations, and in this instance, political importance to the Essenheim, there is a significant amount of prioritising that is required in order to address the needs of operators.

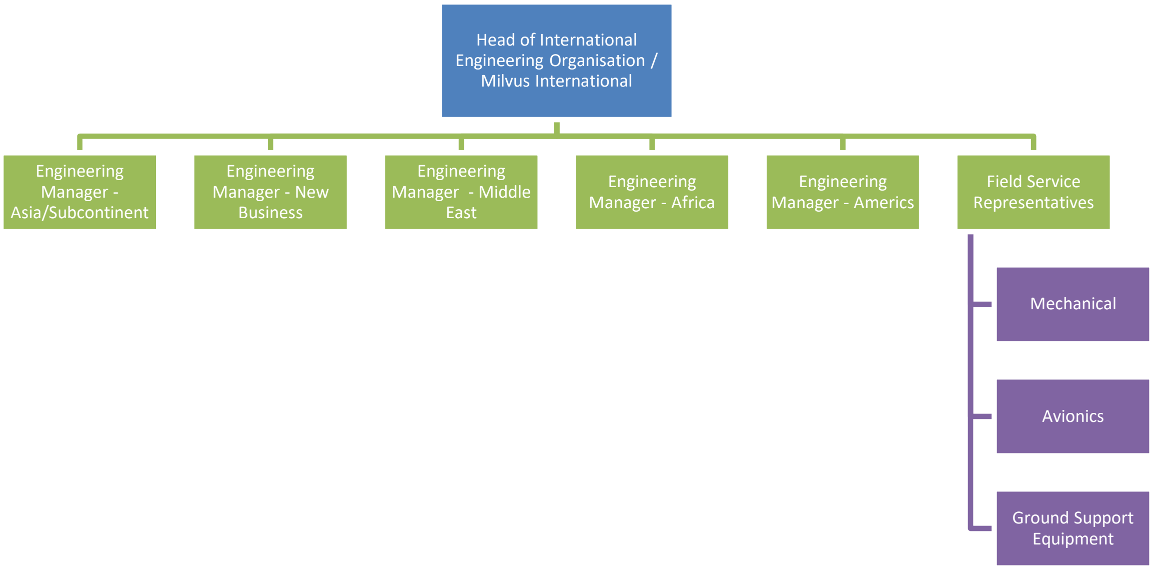

Figure 104: Support engineering group for international Milvus customers

Customer-operators have a close relationship with their respective point-of-contact, discussing issues that they have and what they need. These requirements are broken down into taskings which are passed onto the appropriate discipline-lead for actioning. The point-of-contact then manages the process, keeping the customer-operator informed of progress, and when the tasking is completed, assesses it, when required integrates it, and delivers it to the customer. These taskings can be everything from the need for a repair scheme, to the supply of specific advice, to a request for an investigation, through to the need for a modification. Some tasks can be less than 30 minutes in duration; some can be years.

The respective country managers also interface with other Essenheim-based staff in the Program Management Authority for the aircraft type as required, particularly on the issue of generating new business, and spare-parts material management.

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