Knowledge Management For The Through Life Support Of Aircraft

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Abstract. The effective use of knowledge to deliver outcomes is a key tenet in successful Through Life Support of aircraft – the integrated, performance-driven approach associated with supporting a product during the operational phase of that product’s lifecycle. The rise of performance-based support contracting in defence, and now, in commercial aerospace is forcing the aerospace and defence industry to take a more concerted look at producing suitable aerospace products and capabilities for the lifecycle of aircraft platforms. The management of knowledge in an aircraft program that might last fifty years is important as over the lifecycle of an aircraft program (i.e., ‘cradle to grave’), literally thousands of people will interact with the aircraft type in some way. Tapping into people’s “tacit knowledge”, as well as equipping those operating within the system support role with key knowledge, will be essential in delivering a successful Through Life Support program. This paper considers some observations and ideas from new research into the Through Life Support concept, focusing on how to effectively managing knowledge in this new paradigm, particularly from an aircraft perspective. It then provides some pointers as to how this might apply to the simulation system domain. It’s important that readers understand that these ideas and observations stem from an aircraft system perspective, and thus it is important that they apply these in context to their own simulation system environments carefully.

1. INTRODUCTION

Over the lifecycle of an aircraft program (i.e., ‘cradle to grave’), literally thousands of people will interact with the aircraft type in some way. Each will likely have some level of a unique experience associated with that aircraft type, and hence will have varying degrees of “tacit knowledge” – knowledge which isn’t necessarily captured by some formal process. Whilst much of what is known about an aircraft type is documented, there still exists significant scope to understand how to leverage tacit knowledge to improve both the aircraft capability (and ultimately safety), as well as ‘lean’ the support processes.

When considering the field of “asset management”, “logistics support”, or “Through Life Support”, one finds an increasing reference to the importance of “knowledge management”. Research papers make it clear how a complex system, such as an aircraft, has the potential for long lifecycles, in which significant levels of knowledge can be generated regarding that system[1]. The complexities of such systems lead to a study into knowledge management in the field of systems acquisition by the Defense Systems Management College in the United States. [2]

Other research confirms an increasing realisation by industry (as observed by these authors) that ‘knowledge’ in the logistics domain has often been underutilised and is subsequently wasted. [3]

Managing knowledge within an organisation (and beyond into suppliers and operators) is essential to deliver a Through Life Support program that satisfies customer expectations, and company goals. The purpose of this paper is to provide a snap-shot of a new research project into knowledge management for Through Life Support of aircraft. As such, it’s important that readers apply the observations and ideas presented in this paper in context to their own simulation system environments carefully.

2. THE THROUGH LIFE SUPPORT CONCEPT

As a loose, working definition, the term “Through Life Support” (TLS) is the integrated, performance-driven approach and activities associated with supporting a product during the operational phase of that product’s lifecycle. There is, however, a certain level of ambiguity about the term, and there seems to be no universally accepted definition for TLS.

The concept of ‘support’ in the aerospace context can range from activities such as Maintenance, Repair, Overhaul (MRO), upgrades, access to/provision of critical Intellectual Property (IP), spare-parts-management, in-service part performance tracking and analysis, training, and the provision of other products and services which enable an operator to conduct efficient operations. In essence, it could be argued that TLS is actually about capability delivery – enabling an operations-focused customer to successfully achieve their mission.

The TLS concept is best seen in terms of performance-based servicing arrangements, such as the “Power-by-the-Hour” (PBTH) and “Performance-Based-Logistics” (PBL) contract vehicles (PBL is a term often used in the United States, with “Through Life Support” often used to describe the same concept in other countries like Australia). In each case, a contractor is not paid by the level of activity performed (such as hours spent on maintenance), but rather on the level of defined system availability. PBTH involves a fee paid to a service provider on an hourly operational basis (i.e., the number

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of flight hours, multiplied by a per-hour fee). Other
PBL/TLS contracts may stipulate minimum system
flight-hour availability over a time period, or the
provision of a minimum number of aircraft to a daily
operational ‘pool’ – all for which a fee is paid to the
service provider for delivery, with penalties for not
achieving the availability/delivery targets. It follows
that customers are not paying for activities, but for
outcomes – which is ultimately a capability that the
customer can use to perform a given mission (such as
commercial transport or defence).

There is considerable interest in the Through Life
Support concept within aerospace manufacturing/service industry and aircraft operators.
[4], [5]

However, there are significant challenges for the move
towards this more integrated approach. Questions, such
as “what does it mean for us” have to be addressed by
aerospace companies, independent service providers,
and by operators alike. Issues such as organisational
culture, and even the mindsets of different groups of
people, will likely be the biggest impediment to a wide-
scale adoption of the Through Life Support
methodology – whatever TLS definition is applied! The
authors have observed by talking to industry that these
‘soft’ issues are probably the greatest impediments, with
the management and use of knowledge been of prime
importance.

3. THE ESSENCE OF THROUGH LIFE
SUPPORT

An undergraduate study [6] from RMIT University in
2006 discusses the topic of Through Life Support,
particularly in relation to the commercial aircraft
industry. It defines some of the key tenets/outcomes of
Through Life Support, such as:

- Risk transfer
- Predictable costs
- Higher fleet utilisation
- Reduced Lifecycle costs
- Effective use of knowledge to achieve outcomes
- Delivery of capability through outcomes, not
  just delivery of activities (application of
  ‘systems thinking’)
- Win-win mentality

The International Council on Systems Engineering
(INCOSE) defines capability as follows:

“A measure of the system’s ability to achieve the
mission objectives, given that the system is dependable
and suitable. Examples of capability measures are
accuracy, range, payload, lethality, information rates,
number of engagements, and destructiveness. Capability
measures can be used as performance requirements,
design constraints, and/or technical exit criteria.
Capability is a systems engineering metric.”

As previously mentioned, TLS is about providing the
right capabilities to a customer in order for them to
successfully achieve their mission. This implies that any
TLS program provider must have an intimate
understanding of their customer’s operational
environment and requirements, and must ensure that the
platform delivers the appropriate capabilities to meet
the changing environments of their customers. In the
military context, this might mean new weapons and
sensors. In the commercial arena, it might mean better
cabin experiences, improved fuel-burn performance,
and/or increased navigational performance, such as
incorporating new technologies that enable the “open
skies” concept.

In a previous paper [8], it was observed that the drivers
for Through Life Support included the desire by
customers for mission-focused capability-delivery, the
concept of the “intelligent supplier”, the importance of
availability/utilisation, government-contracting policy,
and the desire of aerospace companies to seek new
business opportunities by providing a “through-life
capability” to customers. It’s interesting to note that the
“mission-focused capability-delivery” concept has been
driving some interesting platform changes, such as
extension of a baseline aircraft’s range to meet an
operator-specific route.

4. OPPORTUNITIES FOR TLS

As mentioned, support/maintenance operations have
often been seen as the after-thought to an aircraft
program. To that end, aircraft maintenance has become
a management mechanism – where the implied
definition of “management” is that of “stopping things
from getting worse”. Its function seems to have been
simply to prevent aircraft from falling out of the sky,
and to ensure people don’t get killed or injured as a
result of an un-airworthy aircraft.

Whilst maintenance is a key activity of Through Life
Support, the outcome-based nature of the TLS concept
will be able to deliver far more than just an airworthy
fleet. It’s actually able to deliver much more, and
instead of simply preventing negative events from
happening, the TLS concept provides the opportunity to
focus on maintaining and even improving capability. In
essence, Through Life Support presents the opportunity
for an intelligent and clever capability delivery
operation that goes beyond the ‘fire-fighting’.

Some of the questions to be asked are “what are the
outcomes of a TLS program?” and “What types of
capabilities will a TLS program be able to deliver?”

The 2006 undergraduate study [6] identified three likely
major outcomes of a TLS program. They included

- Continuous airworthiness (i.e., safe to fly)
- Continuous product improvement
Continuous process improvement

Clearly, ensuring an aircraft platform is safe to fly is paramount to providing a capability. Ultimately, however, TLS will yield a framework for tailoring and preparing platforms to specific missions, and continuously improving that platform to deliver the required capability.

TLS is also able to create new thought approaches to what has been seen traditionally as a pure cost-centre. Maintenance has been seen as a necessary task, one that brings no value to an operator, financial loss due to inaction in an airline’s case; loss of an ability to defend the nation in the case of militaries. However, the “capability-delivery” concept starts to bring about the idea that TLS is actually an investment – that putting money into the TLS operation actually yields to an operator the ability to go and perform their value-generating mission.

The availability driven nature of the performance-based contracts are also driving process improvements. It is in a contractor’s best interests to have no aircraft in the hangers and rather have them in service – it means they are actually getting paid because the system is available. There is an inferred pressure on contractors to ‘push’ the aircraft out of the hanger as quick as possible, and for as long as possible. This business-driver will help bring about the objective for higher fleet availability and thus utilisation.

5. THE IMPORTANCE OF KNOWLEDGE MANAGEMENT FOR THROUGH LIFE SUPPORT

So where does knowledge management fit into the Through Life Support domain? Some real-life examples (two of which the author’s had been exposed personally) provide a good background to the subject:

- A maintenance engineer in the heavy-structures repair shop observes that over a period of time, a specific component corrodes faster than similar components. Whilst they perceive this as ‘fascinating’, there is no process in place to extract that knowledge from that worker in order to improve the product/process. The scheduled maintenance requirement (i.e., flight-hours between inspections) for that component is really dictated by the design & certification phase of the aircraft development, but could be more accurately improved with the knowledge of this worker (and others like him).

- Its noted that aircraft that operate out of one particular port have higher engine degradation rates than aircraft that don’t operate out of that port (due to localised environmental factors – this was something British Airways found with 747s operating in/out of the hot, high & sandy Phoenix).

- The concept of Design-Build Teams in the B777 design effort saved approximately $60m on the design of the passenger doors alone

As the 2006 RMIT University study identified, TLS is about the effective use of knowledge to achieve outcomes. Ultimately the benefits of improved knowledge use and management potentially extend to safety/airworthiness, cost savings, capability availability increases, increased profit, and even staff satisfaction and motivation. It is the clever use of knowledge that is a significant foundation to achieving the vision of a resilient, intelligent support operation.

The knowledge management concept is also vital due to the nature of aircraft programs, in that they can have a lifecycle of many decades, sometimes as much as 50 years. The importance of effective knowledge management strategies in this respect has become clear whilst speaking with engineers and managers within the aerospace and defence industry. This has been particularly marked in the Through Life Support of aircraft platforms.

The Through Life Support phase of an aircraft’s lifecycle is really where the capability of an aircraft design is manifested in the ‘real world’. The design phase is effectively a time of detailed fore-thought to the operation of an aircraft asset, and as such, a number of assumptions would have been made by the design engineers, who would intend the aircraft to operate according to those assumptions. These assumptions and intents will work their way into the physical layout, configuration and design of the aircraft itself. However, these assumptions and intents are often only contained within the minds of the design engineers, instead of being explicitly captured.

Whilst discussing this point with a senior engineering manager, he remarked that when doing a modification or upgrade, the first question that is asked is “why is it the way it is?” The engineers who are supporting an aircraft platform throughout its life constantly ask this question, as it is a prerequisite to undertaking modifications. This is particularly important as, in a sense, and aircraft design is never really complete. It undergoes modification as the aircraft platform is better understood, or as the aircraft is modified with time to be better suited to ever changing missions.

The challenge with management of these design assumptions and intent is the combination of the ‘tacit’ nature of the thinking of the design engineers, and the fact that many of the original designers of the aircraft platform would have moved on as time goes by (especially towards the end of an aircraft platform).

The other challenge is that these design assumptions would have been made in a particular environment (“environment” meaning politically, socially, technologically and economically, as well as physically through such things as atmospheric/weather conditions and structural loadings). Whilst those assumptions might have been valid in that environment, there is no...
guarantee that this will be the case throughout the life of the aircraft type. Over 50 years, the environment in which an aircraft type will be operated in will most likely change. This subject eventually leads to the concept of “Risk Management”.

6. RISK MANAGEMENT AS AN EFFECTIVE KNOWLEDGE MANAGEMENT STRATEGY FOR AIRCRAFT SUPPORT

In talking with industry, it would seem that the concept of “Risk Management” is about protecting oneself from negative events, and doing this through maintaining a “risk register”.

![Figure 1: The Risk Management Process](image)

Figure 1 shows the risk management process, as defined in Australian Standard AS/NZS 4360:2004. When considering the “risk assessment” phase, along with establishing the context, one could argue that the majority of risk management is really about situational awareness. This view has been confirmed when talking with risk managers within industry.

With that in mind, one can begin to consider how this risk assessment process can be put to use in managing the validity of assumptions and design intent. Having a detailed understanding of the environment in which the aircraft will be operating is a key parameter in making a decision on such validation.

For example, the operational environment of the Cold War, where superpowers were arming themselves to protect themselves from one another, has seemingly given way to a new environment today that seems to be focusing more on urban-warfare and dealing with terrorism. Whereas the Cold War seemingly dictated the need to acquire large numbers of fighter aircraft, today’s environment is seemingly focused on intelligence gathering, surveillance, Network Centric Warfare, and techniques and equipment adapted to urban-warfare.

Beyond the ‘softer’ environmental issues, even the physical environment can affect the assumptions and design intent of a system. In early 2007, the metropolitan train service in Melbourne, Australia, suffered significant disruptions due to a major issue with the brakes on a particular make of modern train design. The Siemens-built trains were “overshooting” at stations due to an “unusual loss of traction” [10]. At the time, the train operator was at a loss to understand why the “highly sophisticated” braking system was not functioning properly, and took several weeks to rectify the problem. There was, however, speculation at the time that suggested that the braking system might have been affected by the exceptionally dry weather that the southern areas of Australia had been experiencing. Assuming this to be a contributing factor (something that Connex won’t confirm, even after the authors attempt to make contact with them), then it’s likely that the design assumptions and intents were not valid in the dry, hot conditions of southern Australia, especially since the train units had been designed & built in Germany.

Understanding the operational context that a customer faces daily is also very important. As has been highlighted throughout this paper, an aircraft program is really about delivering a capability to a customer, so they can perform their mission successfully. In essence, Through Life Support is the focus of the program, and not the design phase. That context/environment will change with time, and so the capability needs will change with time too. This is one reason why aircraft undergo a number of upgrades throughout their lives – whether that be the update of the in-flight entertainment system on a commercial airliner, or the inclusion of a new weapon or sensor on a military platform. In each case, it’s to have the capability advantage in a changing environment.

In order to continually deliver the right capability, the TLS provider needs to understand in detail the operator’s needs on a continual basis. Again, this is the concept of “situational awareness” from the perspective of understanding what it is that the customer needs to keep being successful at their mission.

An example of this concept is the Thales Bushmaster personnel carrying vehicle, developed in Australia [11]. The vehicle has been credited with saving a number of lives in Iraq, as the vehicle is designed to carry in excess of 10 personnel in a blast-proof hull. On a number of occasions, it has protected its occupants from roadside Improvised Explosive Devices (IEDs) in Iraq – devices that, when detonated beside other military vehicles, have claimed many lives.

However, the vehicle is not a ‘static design’ – Thales is “in continual contact with Army intelligence to ensure the vehicles meet the demands and risks of the latest [enemy] technology and tactics” [11]. By understanding the evolving environment of its customer, and responding to its needs, Thales is continually providing its customer with the required capability to perform their mission.
It’s important to note, however, that whilst a risk register is a useful tool to track risk, especially at a project level, it may not be an overly useful tool to understand the environment of a customer. Instead, it’s the risk assessment concept which will potentially be very useful, especially if that process is part of the culture of a TLS operation. In a sense, this is customer engineering – just on a continual basis, and highlights the importance of working hand-in-hand between the capability-delivery function, and the operator.

7. SIMILARITIES AND DIFFERENCES BETWEEN SIMULATION SYSTEMS, AND AIRCRAFT SYSTEMS

As has been indicated, this paper examines the knowledge management issues associated with aircraft and other mobility systems. Many simulation systems, however, would probably fall under the category of a ‘fixed’ (i.e., physically stationary) system. There are other differences (and similarities) between simulation systems (especially those used for flight-training), and the aircraft that they replicate. It’s important, thus, to understand that what works for aircraft (with respect to knowledge management) may not work for a simulation system. The following are some of the many similarities and differences between the two systems.

The logistics support footprint for a simulator system (for aircraft/flight training) can be similarly extensive for both the aircraft and the simulator. Talking with industry suggests that simulator systems for aircraft can, in some ways, actually be more complex that the aircraft it replicates. Whilst talking with industry, however, it’s been suggested that the support aspects of a simulation system are not always well thought through. Having a deeper understanding and knowledge of the Through Life Support requirements of such systems is going to be vital, especially if the supply of simulation capabilities is dictated by guaranteed availability and other performance-based outcomes. Using knowledge associated with the operation of such systems will be a vital enabler of successful simulator operations.

Another commonality between simulation systems and aircraft is that of support and upgrade by another firm who is not the OEM. Such firms need to recognise the complexity of such activities, and plan to gain the ‘knowledge-edge’ accordingly. For example, access to Intellectual Property of the OEM is essential, albeit costly. Planning for it is essential, as even if a customer has access to certain product data, one cannot presume they can just pass it on, as contracts with the OEM often stipulate the use of data only by the operator (with any other support organization having to pay substantial amounts of money to access the same information). These challenges should not be underestimated, and planned for carefully.

There are, of course, a number of differences. Clearly, an aircraft requires a little more effort to physically place into maintenance, considering its mobile nature. Shutting a simulator down for maintenance is therefore, probably, a little easier (although still must be managed to still meet the needs of the training organisation). In addition, the regulatory aspects of simulation systems extends predominately to fidelity, and hence components that are used in the system do not need to go through the same rigorous levels of compliance, as they would on an aircraft.

Whilst a simulation system is designed to replicate reality, there always will remain gaps between how an aircraft will respond to a situation in ‘reality’, versus how it is simulated in a training aid. It’s essential that there be a very detailed understanding of the differences (“Fidelity Delta”) [12] – not just from the initial operating date, but throughout the life of the simulation system (i.e., on a continuous basis). Using the knowledge of customer operations that the aircraft manufacturers will have will probably be an important way of doing this through-life, especially if aircraft experience a scenario not previously planned for or thought of. However, this knowledge must be contextualised into the simulation environment, understanding the differences between the two operations.

8. APPLICATION TO SIMULATION SYSTEMS

Whilst readers are strongly encouraged to draw their own conclusions with regards to effective knowledge management of simulation systems, the following are some points that might aid the reader in that process.

As has also been described, there is significant interest by defence organisations in performance-based contracts associated with significant military systems. This will undoubtedly apply to training simulation systems, and other defence-specific simulation products, if this has not happened already. As such, the vendor of such support services needs to keep in mind some of the objectives of Through Life Support. Based on the previous discussion under Section 4 (the major outcomes of TLS), perhaps the following apply as outcomes of the performance-based support of simulation systems:

- Continuously ensuring the simulation system complies with all regulations, and complies as a quality product (for example, it’s accurate, it’s reliable, it’s available for the customer to use, and it’s up-to-date). This incorporates a continuous, thorough understanding of the Fidelity Delta, and managing the expectations of operators accordingly.

- Continuously improving the simulation system to incorporate new data packs (that reflect true operating conditions more accurately), increasing system reliability and availability, reducing downtime, and facilitating easier modifications and maintenance to the system. This is product specific improvement, and goes to making sure the system provides the needed capability at the present moment (just keeping it “up to scratch”).
• Continuously improving support processes – how can we work differently to be more efficient and effective? One will probably find that improving the simulation product will make the support processes more efficient (for example, upgrading a component so that in future, it will be quicker to repair)

Defence systems are also dynamic in nature – they don’t stand still! In a sense, they never reach a point of perfection, but keep on evolving to provide the capability that is required, and adapt to the environment that system needs to thrive in (such as the Bushmaster example). Simulation system providers will need to organise their program/project management planning and execution to reflect this reality. This includes continuously scanning the environment and context, looking for risks (and opportunities) in the various dimensions they present themselves in (including the physical operating environment, the political environment, the economic environment, the organizational environment, the cultural environment, and technological developments). Being aware of the change that is taking place is vital, especially as simulation systems try to replicate ‘the real world’.

An important note for providers of training simulation systems (especially those that replicate an aircraft or other complex mobility system), is to listen and work closely with the system’s manufacturer. Look for updates, even small ones that might affect a fleet for which the simulation system tries to replicate. Even local environmental issues, or slight fleet differences, can potentially be evident to those who are training in a synthetic environment.

It follows that a TLS operation is really about serving – in the case of defence, it’s serving, for example, the pilots who serve in an Air Force, who are ultimately serving the nation. It’s important to listen to customers and their issues, complaints, needs, and suggestions. Having an attitude that seeks to make a customer successful in their mission is vital to ensuring the TLS concept works. Interestingly, this will likely have positive financial implications. A marketing expert known to the authors indicates that people are willing to pay more for excellent service that truly seeks to make one excel in a particular area (for example, a sales person who puts in effort to find clothes that really suit somebody will probably sell more clothes at a premium price).

This “being aware” characteristic of knowledge management is critical in a Through Life Support operation of any type of system. However, the continuance of design knowledge and intent (the design “why”) is also critical. For a simulation system, this will probably be important too.

The authors would be very keen to hear from readers exactly how “knowledge management” (what ever it is perceived to mean) applies to simulation systems, especially in light of the comments of this section.

9. CONCLUSION

The aerospace business is changing from a traditionally product driven environment to a more capability driven environment. As a consequence, the product supplier must take responsibility of the serviceability of the product from design, manufacture, operations to disposal. This change is significant as contractual capability/serviceability guarantees can be costly if they cannot be met.

It could be argued that the Through Life Support concept is not just a phase in an aircraft’s lifecycle, but rather it is a driver of change that will redefine the way entire aircraft programs are planned, executed, and managed. The majority of aerospace manufacturer/integrator effort might be more concentrated on the operational phase of the platform’s lifecycle, with the design/manufacturing phase really about developing, as part of a capability system, a flexible platform to deliver the outcomes necessary to supply the right capability at the right time to the right customer.

As such, having a detailed knowledge of the customers’ domain is essential to delivering capability throughout the life of a system. Since the lifecycle of aerospace systems can be many decades, maintaining the understanding of design intent, as well as continually monitoring the environment in which a system is operated, is essential to the successful delivery of capability, and ultimately mission assurance.

Finally, it is hoped that this as the research project continues, conclusions can be drawn that will have relevance to simulation systems. This potentially includes some strategies for environmental scanning, managing the system Fidelity Delta, and an understanding on how OEM knowledge can be used to further improve the capability of a system through its life.

REFERENCES


