Interoperability & Aircraft Stores Certification – An Australian Perspective on Where To From Here

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ABSTRACT

The level of interoperability of aircraft and stores is vital to Australia being able to fly and fight with our allies. Interoperability (ie the ability of systems, units or forces to provide services from other systems, units or forces and to use the service so exchanged to enable them to operate effectively together) is usually given a very high priority early in aerospace weapons programs in setting the standards required and then seems to be left behind when fiscal realities start hitting home. Standardisation can occur within the areas of doctrine, procedures and equipment at three possible levels of standardisation to achieve the required level of interoperability: Compatibility, Interchangeability and Commonality.

This paper will discuss Australia's perspective on the extant development and agreement of better, internationally recognised, technical standards addressing structures, electrical interfaces, EMC/EMI/HERO, safe escape, flight termination systems, safety templates, risk management and, most importantly, a method to verify the level of interoperability.

The level of interoperability for nationally "certified" aircraft stores configurations needs to, however, mature beyond such a technical emphasis to one of a people emphasis by addressing the command and control and organisational elements to achieve certification of interchangeable aircraft stores capabilities. The current initiatives of organisations such as the Air Standardization Coordinating Committee, the NATO Military Agency for Standardization and commercial standardisation organisations that will affect how future aerospace weapon systems will be integrated to achieve interoperability between joint, allied, and coalition forces will be critically reviewed and options discussed to increase awareness of the challenges facing us.

1. INTRODUCTION

Dead targets are our product in war. Our product in peace is sorties that train people to make dead targets.

General John Jumper,
What I Believe, 2000, Now US Air Force Chief of Staff

The Australian Defence Force is currently acquiring a mix of advanced air delivered weapons under a number of major and minor acquisition programs to further enhance the ADFs future combat air to air, air to ground and associated training capabilities to achieve tailored effects. These programs are intended to be 'fully interoperable' with our allies principally via agreements and standards established by the Air Standardization Coordinating Committee (ASCC). Capability management and systems engineering techniques are being applied across the majority of areas within the Department of Defence in Australia.

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This paper will assess how these interoperability initiatives are affecting aircraft stores compatibility clearance and certification practices and the systems engineering being applied during acquisition of new aerospace combat capabilities.

1.1 MOTIVATION

All Australian selected DMPI's serviced on the first pass. *ASCENG Vision*

This paper will briefly address the major ongoing initiatives in the ADF to streamline the acquisition of operationally suitable and effective aircraft stores capabilities to meet defined operational requirements across all three services. Such acquisitions include *inter alia* Australia's Defence Materiel Organisation's (DMO) Project AIR 5400 which is concurrently procuring the UK AIM-132 ASRAAM[1] and US AIM-120C AMRAAM for air to air operations from RAAF F/A-18 Hornet aircraft with upgraded avionics and helmet mounted sight, the Project AIR 87 acquisition of the Tigre armed reconnaissance helicopter and AIR 6000 / New Aircraft Combat Capability with F-35 Joint Strike Fighter. Similarly several DMO Projects are addressing air to ground capabilities including: Project AIR 5398 with the AGM-142E Raptor[2] Imaging IR guided missile with blast and penetrator warheads and the associated AN/ASQ-55 Data Link Pod on the F-111C AUP aircraft, AIR 5418 which is considering Boeing SLAM-ER, Taurus KEPD 350 or AGM-158 JASSM for AP-3C and F/A-18, AIR 5409 which is considering GPS aided weapons and JP 2070 which is procuring Eurotorps *u*90 Light Weight Torpedo for AP-3C and those maritime targets and submarines.

Figure 1. F-111E with the US AFRLs Powered LOw Cost Autonomous Attack System (PLOCAAS) Subpack during RAAF MIL-HDBK-1763 Fit Test at Eglin AFB.

1 See a separate presentation about the F/A-18 ASRAAM integration, clearance & test program being made at this Symposium by Pierens and on WSAS by Akroyd (2004) at [1] and [2] respectively.

2 Originally designed and manufactured by Rafael for the Israeli Air Force, the POPEYE missile has also been introduced into USAF service with the B-52H aircraft as the AGM-142A HAVE NAP missile. The AGM-142E was developed by Rafael with Lockheed Martin Missiles as a joint venture for the USAF, RAAF, et al.

Australia is also clearing a number of aircraft stores combinations for the conduct of testing in support of advanced concept technology demonstrators such as the US AFRL miniature munitions program shown at Figure 1 in support of PLOCAAS (Powered Low Cost Autonous Attack System) Subpacks from F-111G weapons bay and aeroacoustic and separations technology[3], GBU-38 Joint Direct Attack Munition (JDAM) married with a Defence Science & Technology Organisation (DSTO) designed and Hawker de Havilland Extended Range wing kit (GBU-38 JDEAMER) concept demonstration from F/A-18 as the carrier aircraft and potentially the US Loitering EW Killer (LEWK) or PLOCAAS from the AP-3C.

Please note that the ideas in this paper are from unclassified, open sources and are definitely those of the author. They are intended to promote awareness and discussion on the challenges the ADF faces in improving the degree of interoperability with Australia's major allies as we transition to a tailored effects based defence force.

Figure 2. RAAF F/A-18 operating in the 'Sandpit' with USAF configured GBU-12 and RAAF AIM-120 AMRAAMs during Operation FALCONER / IRAQI FREEDOM[4]

1.2 DEFINITIONS

Please also note that the significant definitions and buzzwords used in this paper are included as footnotes and the majority of acronyms are also summarised at Annex A.

[3] For which another joint RAAF/USAF presentation is being made at this Symposium and covered at the AIAA Conference by Grove et al (2003) at [3].

[4] Wherein 100% of Australian designated DMPIs were 'serviced' on the first pass – the first less than 24 hours after testing and clearance by ARDU & ASCENG!

2. AIM

The aims of this paper are to:

a. identify the initiatives being undertaken to enhance the interoperability of air armament with ASCC and TTCP member nations;

b. establish the context of aircraft stores clearance & certification in Australia; and

c. promote discussion on the future application of contemporary systems engineering to improve the interoperability of aircraft stores configurations.

This will be implemented for each of these aims by describing "what it is" and what its "application during the systems life cycle" is.

3. BACKGROUND

If you are thoroughly conversant with tactics, you will recognise the enemy's intentions and have many opportunities to win.
Miyamoto Musashi, Samurai Swordsman

Australia is an island nation the size of the Continental USA, with a population of just over 20 million, a Gross Domestic Production of over $(US) 500 Billion, no 'nation state' enemies or a direct military threat to the sovereignty of the nation. Australia has historically provided defence personnel and equipment for almost every UN peacekeeping operation since the UN's inception and has been 'punching above its weight' during the War on Terror. With the strategic situation in mind, the Commonwealth Government has maintained defence expenditure at just over 2% of GDP for the last 10-15 years. As part of the 1997 Defence Reform Program the Government decided that the ADF will be composed of a uniformed force of 50 000 with some 13 500 Air Force personnel and a greater (true) involvement of Reserve forces.

This situation was continued by the ADF involvement and leadership of the UN operations in East Timor in Sept 1999 and Australia's relatively significant support to the War on Terror resulting from September 11 and Bali Bombing on 12 Oct 2002. Strong public support was evinced during the review prior to the Defence White Paper in 2000 and with the subsequent War on Terror significant funding increases in the subsequent Federal Budgets and significant changes proposed to the Defence Capability Systems Development and Management framework. The proposed changes have been instituted to address initiatives such as Acquisition Reform, formation of the Defence Materiel Organisation from the previously separate Defence Acquisition and Support Command organisations, Government's requirement for increased engagement in the capability development and approval process, and increasing Australian industries involvement to achieve self-reliance though the whole of life.

As Australia today does not indigenously design, develop or manufacture complete military aircraft or aerospace weapons, these activities are conducted overseas. Traditionally much of the ADF's aircraft stores clearance work has been minimised in a lot of areas by information being provided by the original operators of the aircraft who have previously certified weapons similar in type and role to those intended for use by the ADF thereby providing a clear basis for approving aircraft stores clearances by analogy[5][6]. This situation has changed significantly with the ADF introducing weapons into all three services that are not currently operated by the original aircraft operators or have not previously cleared for use on other remotely similar aircraft[7]. Further details of the aircraft stores combinations being acquired are covered more extensively at Tutty (2003) at [4].

5 A form of reasoning in which similarities are inferred from a similarity of two or more things in certain particulars.; or an agreement, likeness or correspondence between the relations of things to one another.

6 **Similarity.** State of being similar, a point of resemblance. In the ADF airworthiness parlance this indicates that an acceptable Certification Basis has been established by another recognised airworthiness agency.

7 The prime example is the RAAF being the sole operator of the F-111 aircraft since 1997 and the need to integrate standoff weapons to increase the aircraft's survivability due to the cost to incorporate low observable technology.

These imperatives require Australia to not only be self-reliant in undertaking aircraft stores clearance and certification but be actively engaged in ensuring that international standards[8] and methods being used are suitable to the ADF, the Australian environment[9] and the levels of interoperability identified with our allies and coalition partners. Historically, this has been primarily conducted via a number international standardisation fora (as per the summary included in Annex D), the primary one being that of the ASCC between Australia, Canadian, NZ, UK and US.

4. INTEROPERABILITY, EXPERIMENTATION & NETWORK ENABLED WARFARE

What is it.

The **ASCC** defines **interoperability** as:

the ability of systems, units or forces, to provide services to, and accept services from, foreign systems, units, or forces and to use the service so exchanged to operate together effectively.

The three levels of **standardisation**[10] as used and accepted by ASCC for **interoperability** are:

- **Compatibility** the suitability of products, processes or services for use together under specific conditions to fulfil relevant requirements **without causing unacceptable interactions.**
- **Interchangeability** the ability of one product, process or service to **be used in place of another** to fulfil the same requirements.
- **Commonality** the state achieved when **the same** doctrine, procedures, or equipment are used.

The three main areas of standardisation are in the areas of **doctrine**, **procedures and equipment.**

Experimentation. n. the act or practice of making experiments; the process of experimenting; a product that is the result of a long experiment. [Macquarie Concise Dictionary] In the scientific method, an **experiment** is a set of actions and observations, performed to verify or falsify a hypothesis or identify a causal relationship between phenomena. The experiment is a cornerstone in the empirical approach to knowledge. [see Wikipaedia, an on-line scientific dictionary at: http://en.wikipedia.org/wiki/Scientific_method]

Network enabled warfare. Everyone involved in defence should be fully aware of the concept of network-centric warfare (NCW) postulated by Cebrowski et al, (1998) at [5], but what is it actually? In its simplest terms Kopp (2003) at [6] characterises NCW as "the military equivalent of the information revolution" and "over the coming decade we will see the world divide into nations that employ NCW techniques, and other that do not, be it reasons of ideology or operational/technological incapacity'. For the purposes of this paper, network enabled warfare is defined as '***the state when fighting units, sensors and decision makers are linked in a robust, continuous way that increases situational awareness and the capacity to act decisively that is superior to their adversaries***'[11].

8 A **standard** is a description of a process, material, or product meant for repeated use in one of more applications and covers materials, processes, products and services.

9 One should envisage Middle Eastern temperature extremes and conditions in Central Australia with high humidity thrown in as well for good measure in the Northern Territory Australia.

10 These three levels of standardisation are the most important terms and concepts for determining the future levels of interoperability for **doctrine, procedures and equipment** for the ASCC member nations.

11 This is an amalgam of definitions drawn by the author primarily from Cebrowski (1998) at [5], Kopp at [6], ASCC and Muir (2003) at [7].

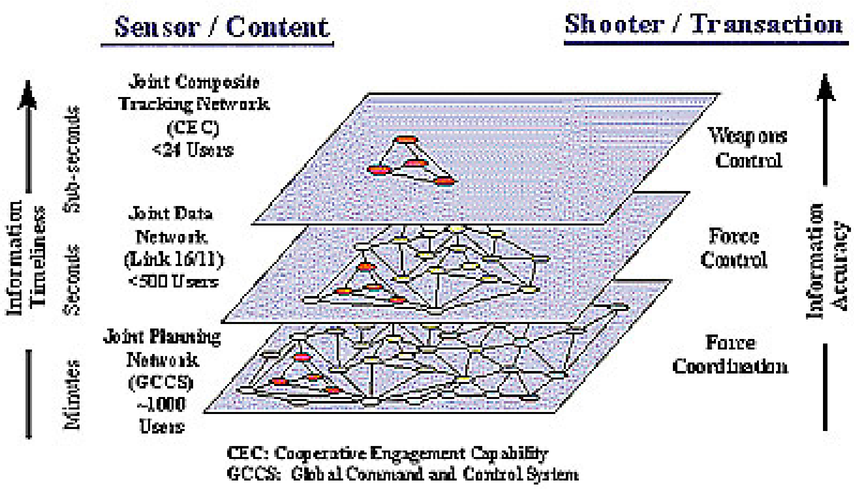


Figure 3. Cebrowskis prescient view of NCW from [5]

Application during the systems life cycle - Interoperability

Australia has also been exploring the wider ramifications of interoperability based on ASCC nations experience in coalition operations. Clark & Moon (2000) et al have highlighted in studies of C2 support at [8] that there are two major aspects: planned (or technological) and flexible (extemporaneous). The technical level of systems interoperability required must be planned well in advance (which is where ASCC WP 20 has been focused to date). Where the interoperability focus is on processes rather than systems, the interoperability achieved can be more flexible. Clark & Moon (2000) then explore use of the US DOD Levels of Information Systems Interoperability (LISI) model at Table 1 which has been used extensively for capability development and force structure planning activities.

Increasing interoperability

LEVEL (environment)			Interoperability attributes: Procedures	Applications	Infrastructure	Data
Enterprise (universal)	4	c	Multi-national	Interactive	Multi-dimensional topologies	Cross-enterprise models
		b	Intra-government			
		a	Defence department	Object cut & paste		Enterprise models
Domain (integrated)	3	c	Domain	Shared data	WAN	DBMS
		b		Grp collaboration		Domain models
		a		Txt cut & paste		
Functional (distributed)	2	c	Common Operating Environment	Web browser	LAN	Program models & advanced
		b		Office software		
		a	Program	Adv. messaging	NET	data formats
Connected (peer-to-peer)	1	d	Standards compliant	Basic messaging	Two way	Basic data formats
		c		Data file transfer		
		b	Security profile	Simple interaction		
		a			One way	
Isolated (manual)	0	d	Media exchange procedures	Not applicable	Removable media	Media formats
		c	Personnel access controls		Manual re-entry	Private data
		b				
		a				
		0	NO KNOWN INTEROPERABILITY			

Table 1. US DoD LISI Model - from [8]

The US LISI model has been used and extended to develop an Organisational Interoperability Maturity Model by DSTO to explore five layers of support for C2:

- C2 frameworks
- C2 processes
- Information Management
- Information Technology &
- Telecommunications.

This model has been extremely useful for assessing operations with coalition partners at differing level of technical interoperability and is strongly recommended for further reading[12]. Note that the ASCC WP 45 on Air Operations and Doctrine are also exploring some of these wider issues of interoperability and are producing documents that are fundamental to air armament and are well worth following up[13].

	Preparedness	Understanding	Command Style	Ethos
Level 4 Unified	Complete - normal day-to-day working	Shared	Homogeneous	Uniform
Level 3 Combined	Detailed doctrine and experience in using it	Shared comms and shared knowledge	One chain of command and interaction with home organisation	Shared ethos but with influence from home organisation
Level 2 Collaborative	General doctrine in place and some experience	Shared comms and shared knowledge about specific topics	Separate reporting lines of responsibility overlaid with a single command chain	Shared purpose; goals, value system significantly influenced by home organisation
Level 1 Cooperative	General guidelines	Electronic comms and shared information	Separate reporting lines of responsibility	Shared purpose
Level 0 Independent	No preparedness	Voice comms via phone etc	No interaction	Limited shared purpose

Table 2 DSTO Organisational Interoperability Levels & Attributes - from [8]

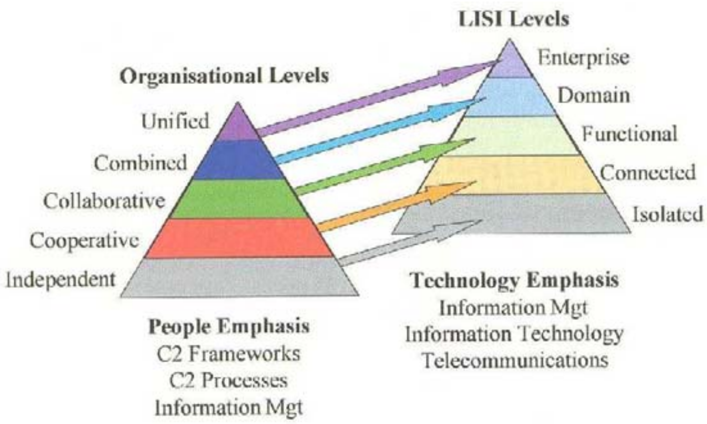


Table 3. LISI and Organisational Interoperability models – from [8]

12 A soft copy of the paper by Clark & Moon (2000) at [8] has been provided by the author to the Symposium organisers for those interested.

13 See ASCC AIR STD 45/3 on Joint Air & Space Operations Doctrine et al for example. ADVPUB 85-XX is also particularly noteworthy.

Experimentation through The Technical Cooperation Program (TTCP) and Joint Warrior Interoperability Demonstrations (JWID) between the five ASCC nations are also fundamentally affecting the equipment Australia is intended to procure for future command and control of the operational elements of the ADF to improve the communications to achieve higher organisational interoperability of joint and coalition forces. The JWID in 2002, replayed the UN operation in East Timor with different communications options to achieve higher interoperability levels than that noted by Clark & Moon (2000) for the actual operation. McKenna (2003) at [10] also provides details of the 2003 Coalition C4 Tests to determine how all the technologies might work in action. The JWID exercises are strongly supported by the ASCC nations and are certainly providing the foundations for Australia to experiment with technologies as part of a system rather than acquiring bit parts and then finding the operational concept is fundamentally flawed when used with our allies.

Application during the systems life cycle – Network enabled

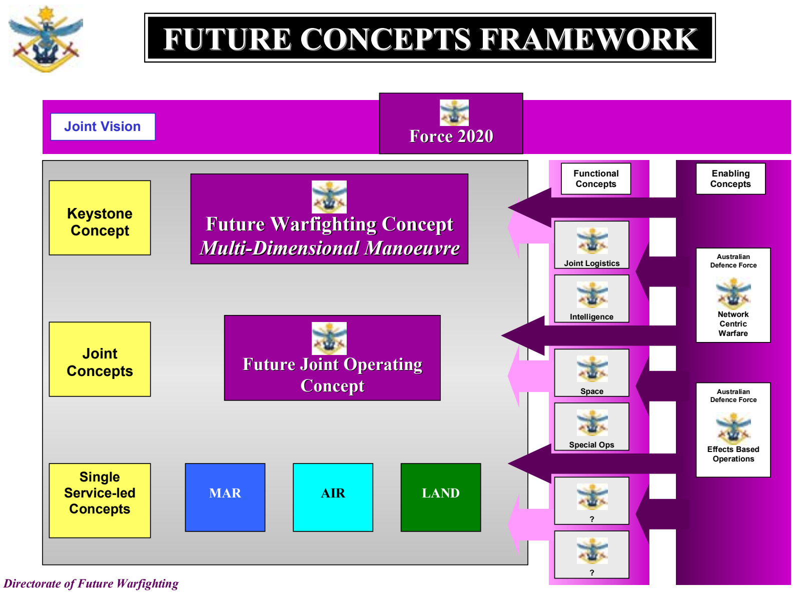
As the ADF transforms itself into a truly integrated joint defence force the level of interoperability between system, units, and forces becomes ever more important. This level of integration wherein system of systems are able to work together is extremely difficult to plan for and implement successfully. Therefore an integrated defence architecture framework is being developed to address this.

The Australian Defence Doctrine Publications (ADDPs) outline the joint vision of the ADF as developed by the ADF Warfare Centre. ADDP–D provides the foundations of our military doctrine while ADDP-D1 to 4 expand on our approach to warfare, the Force 2020, Future and Joint Warfighting Concepts.

The lead concept, *Force 2020,* articulates a joint vision for the ADF for the 2020 timeframe, and informs all subordinate concepts. The key concepts are:

- **A seamless Force – 'Beyond Joint'**
- **Network-Enabled Operations**

To enable these core concepts to become a reality, interoperability of communications systems is vital so that we can communicate effectively in the interoperability scenario provided later in this paper for example.



This integration becomes non-trivial very quickly with the defence acquisition system trying to buy and put into service the various sub-systems. Also of importance is the 'conceptualising' required for these systems to work together in a campaign or actual operations with other joint forces as shown in the following figures. Kopp (2003) at [6] has some interesting insights into how smooth the information revolution was for the commercial/business world in grappling with the complex, rapidly changing technology and how to influence the thinking processes of a great many people.

Gartska (2000) at [9] (included as Enclosure 7), notes that '*A network-centric force has the capability to share and exchange information among the geographically distributed elements of the force: sensors, regardless of platform; shooters, regardless of service; and decision makers and supporting organizations, regardless of location. In short, a* ***network-centric force is an interoperable force, a force that has global access to <u>assured</u> information whenever and wherever needed***'[14]. Portions of Gartska (2000) worth noting here further in part due to it's applicability to air armament:

> Continued exploration of the relationships between information and combat power requires both new analytic tools and new mental models. Ongoing activities to develop metrics for the information domain are hacking through dense conceptual "underbrush" in an attempt to identify a path that can be navigated. A conceptual model currently being developed collaboratively by an Information Superiority Metrics Working Group is focused on characterizing the relationships between shared information, shared situational awareness, and the processes of collaboration and synchronization. A key element of the model is a focus on three domains: the physical domain, the cognitive domain, and the information domain. [15] This conceptual model builds upon a construct proposed initially by Fuller (1917),[16] and refined in *Measuring the Effects of Network-Centric Warfare*[17]
>
> - **Physical Domain:** The physical domain is the traditional domain of warfare. It is domain where strike, protect and maneuver take place across the environments of ground, sea, air and space. Comparatively, the elements of this domain are the easiest to measure, and consequently, combat power has traditionally been measured primarily in this domain. Two important metrics for measuring combat power in this domain, lethality and survivability, have been and continue to be cornerstones of military operations research.
> - **Cognitive Domain:** The cognitive domain is the domain of the mind of the warfighter and the supporting populous. This is the domain where battles and wars are won and lost. This is the domain of intangibles: leadership, morale, unit cohesion, level of training and experience, situational awareness, and public opinion. This is the domain where tactics, techniques and procedures reside. Much has been written about this domain, and key attributes of this domain have remained relatively constant since Sun Tzu wrote *The Art of War*. The attributes of this domain are extremely difficult to measure, and each sub-domain (each individual mind) is unique. Consequently, explicit treatment of this domain in analytic models of warfare is rare. However, a methodology that begins to address key attributes and relationships of this domain has been proposed by Harmon in the context of "entropy based warfare.' '…With network-centric operations a fourth input is added, digital information that is exchanged from external sources, such as other fighter aircraft, or airborne surveillance and C2 aircraft, over a network [see this paper Figures 4 and 5 below].[18]

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14 Garstka (2000) at [9] notes that 'a force with these capabilities is not known to currently exist in any of the US Military services or in the armed forces any our Allied or Coalition partners.' Which is still true today.

15 The Information Superiority Metrics Working Group is a community of interest, sponsored by ASD(C3I), JCS/J6, and JFCOM/J9. Information at http://www.dodccrp.org – this open source website is well worth visiting for the aficionados as well as the neophyte.

16 J.F.C. Fuller, 1917, *The Foundations and Science and War*

17 VADM Arthur K. Cebrowki, USN, Written testimony to hearing *on Defense Information Superiority and Information Assurance – Entering the 21st Century*, held by the [US] House Armed Services Committee, Subcommittee on Military Procurement, February 23, 1999.

18 Harmon, M, *Entropy Based Warfare: A Unified Theory for Modeling the Revolution in Military Affairs*. Booz-Allen & Hamilton, 1997

The issue then really becomes one of data fusion and confidence in the provenance of the data shared and shown.

Figure 2: 4 vs. 4 Air-to-Air Engagement

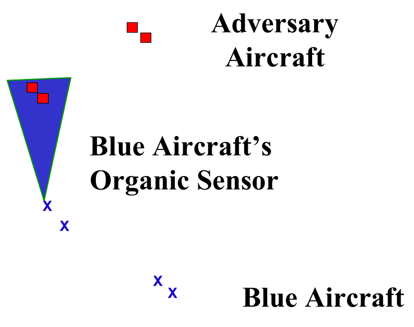


Figure 4 Garstka (2000) scenario example for NCW operations at [9] – see Enclosure 7

Figure 4: Information Sharing with Network-Centric Operations

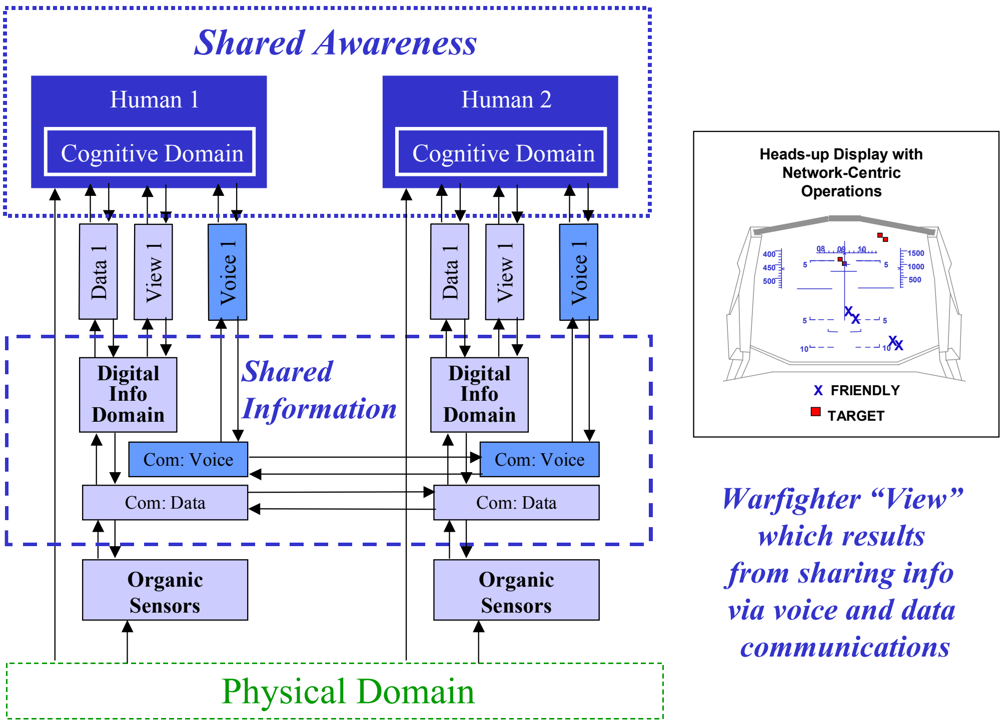
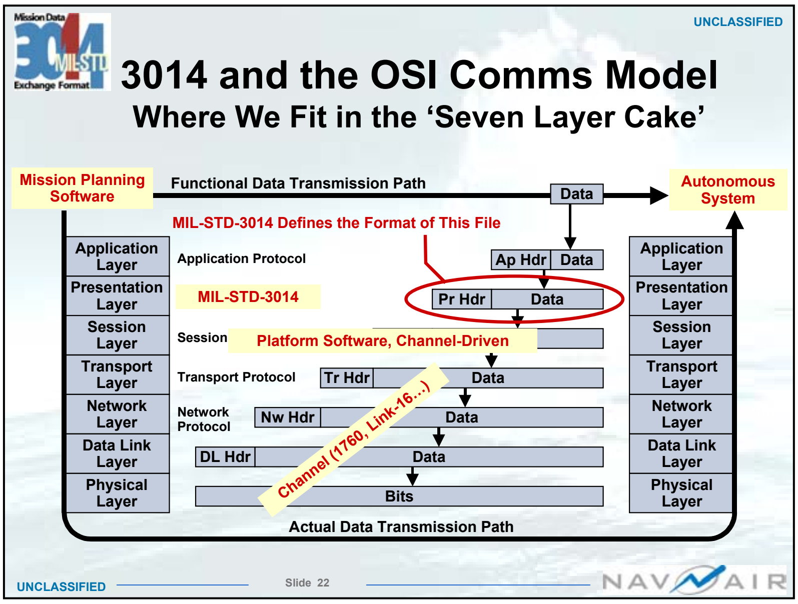


Figure 5 HUD with NCW Shared Comms data and Friendlies and Targets - Garstka (2000) at [9] - see Enclosure 7

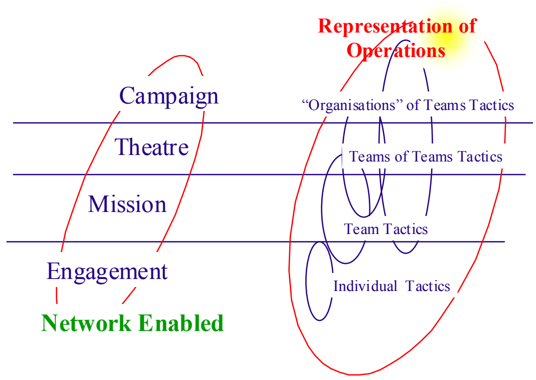
The keys issues as well summarised by Kopp (2003) at [6] are:

1. Security of information.
2. Robustness of transmission.
3. Transmission Capacity.
4. Message and signal routing.
5. Signal Format and communications protocol compatibility – see figure below wrt the US OSI model and MIL-STD-3014.



Kopp [6] also notes that the US Marine Corps were much better able to integrate in a NCW environment with USAF, USN, RAAF and RAF fighters than were US Army units due to 'a Service culture which aims to break down distinctions between specialisations and a training regime centres in closely integrated all-arms operations'. He has expressed concerns with the 'growing gap between the US military and the EU military with the perceived reluctance to invest in digitising their combat platforms'. RTO comments are invited on this view which gravely concerns the ADF, if true[19].

Australias experimentation program should also receive a significant boost when the ***Aerospace BattleLab Centre*** of DSTO is progressed for all aerospace applications. The goal at Farrier et al [17] is to ensure the current disparate aircraft simulators and simulations in the various M&S are interoperable. This philosophy will hopefully extend to an evolutionary model for OFPs and simulators not just from the aircraft perspective but also the weapons fly out models as well so that the best representation of operations is possible for the intended experiment as shown in the following figure. DSTO and dstl and AFRL are investigating the use of a common modelling



[19] The author should be able to see who actually reads this paper, if no-one bites on Kopps view here!

framework for weapons using an interoperable systems known as MSTARS. The RAAF intends that these models be not just research design tools but also are made applicable to inservice and acquisition weapons of the future.

This work should contribute to experimentation of use of the Hawker de Havilland & Boeing Capability Technology Demonstrator program for GBU-38 JDAM-ER as shown at Figure 6 and for improving interoperability of complete systems such as at Figure 7 not the 'bit parts' of the system.

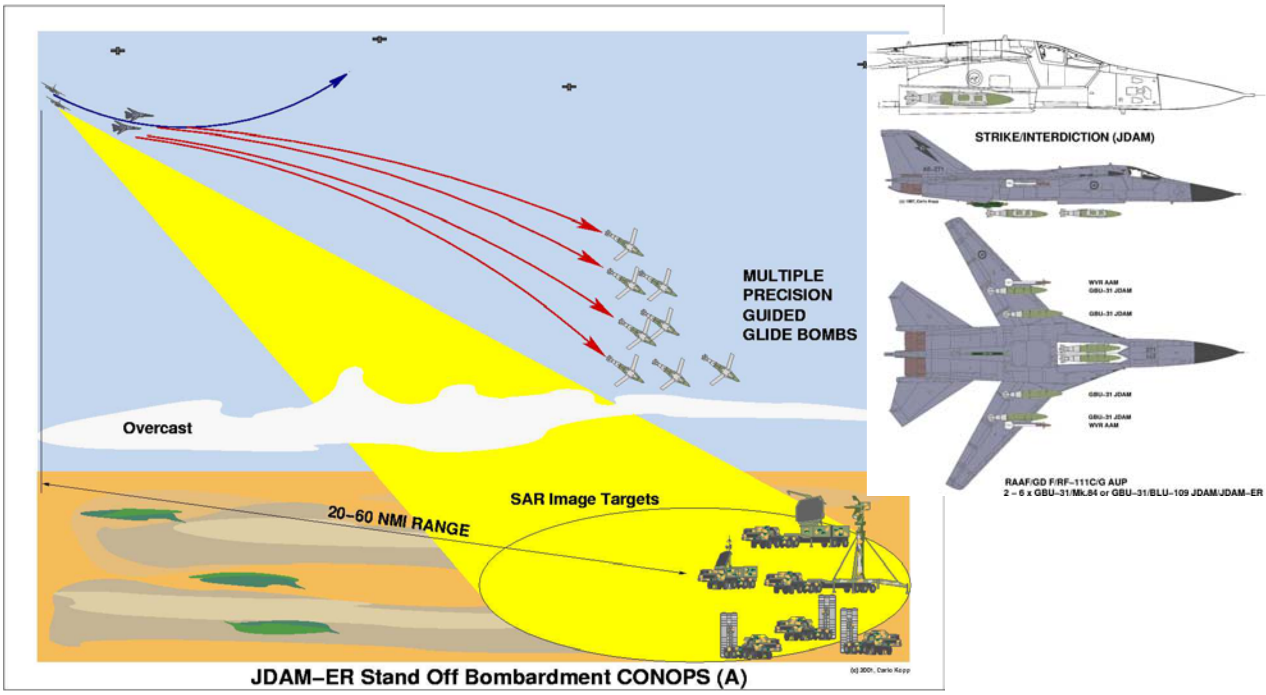
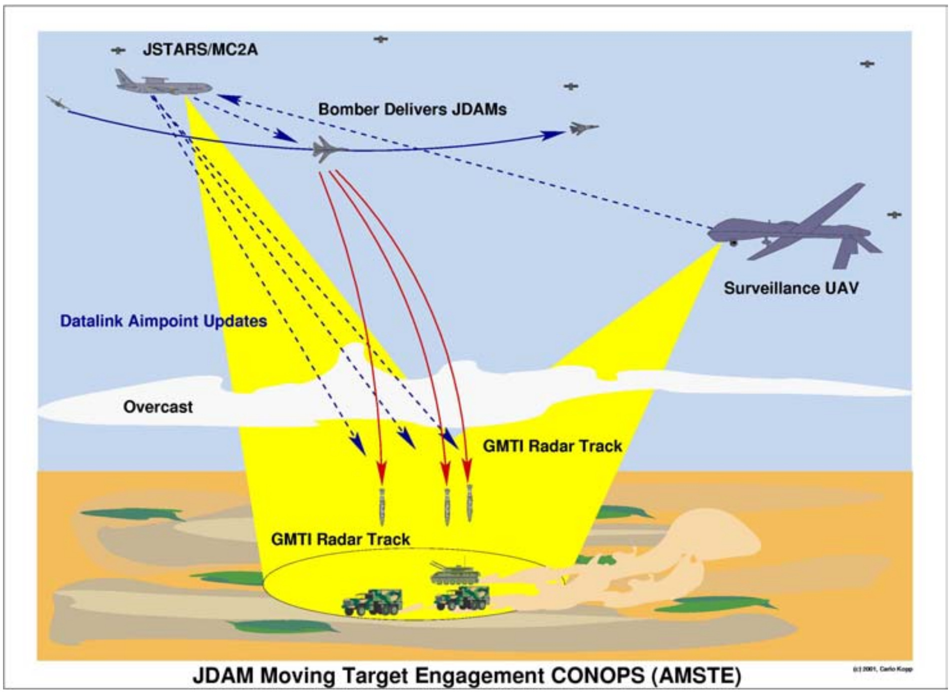


Figure 6. JDAM and JDAMER Concept of Operations – figures courtesy Kopp [6]



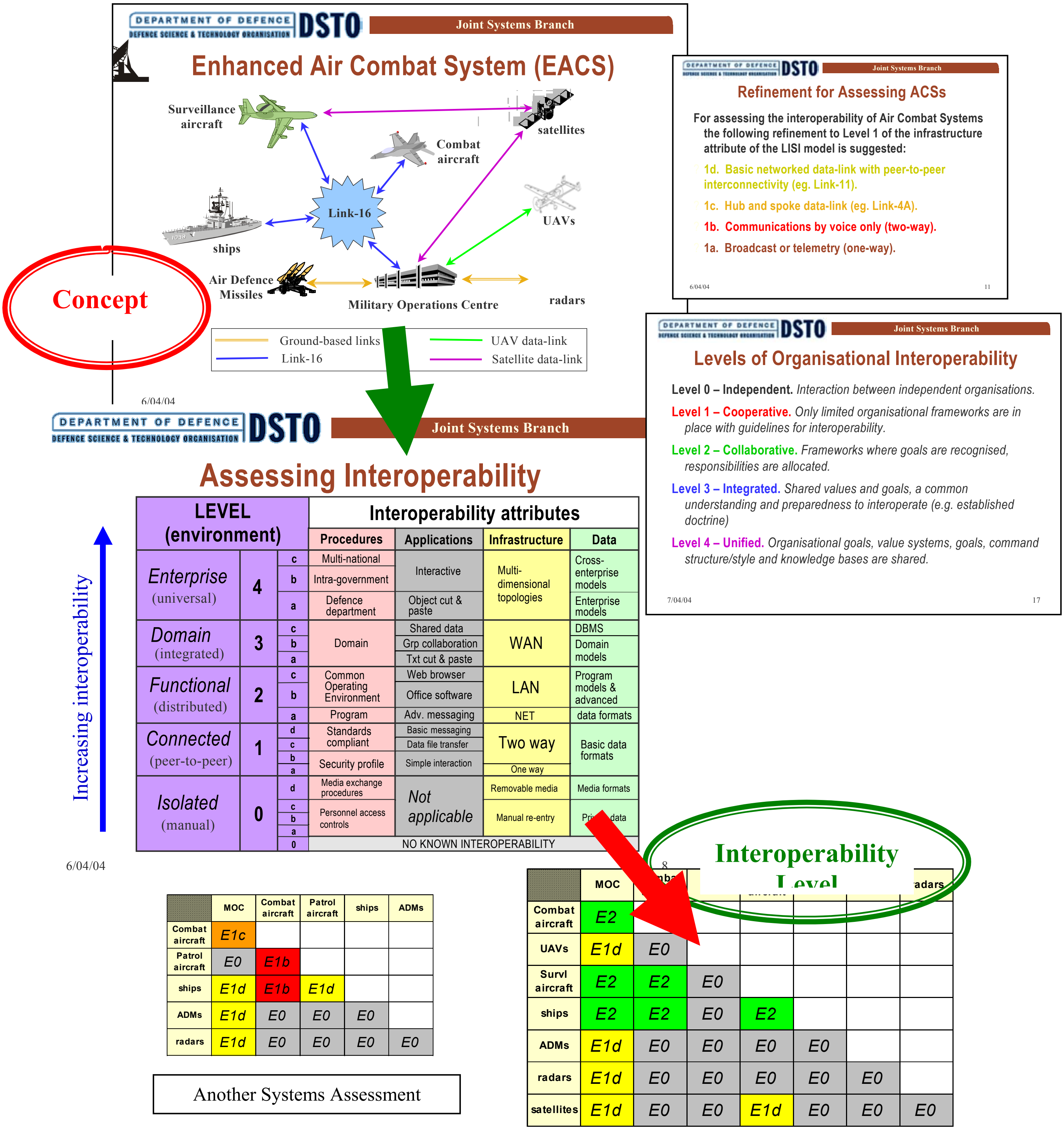


Figure 7. DSTO Interoperability Enhanced air combat system – figures courtesy of Moon [8]

5. ASCC

5.1 What is it.

The last decade has seen significant changes to the structures and activities of military forces and the environment in which they must operate. In response to the changing international operational environment, the ASCC continues to evolve its activities to facilitate coalition air operations for the participants: Australia, Canada, NZ, UK and the three US services. The ASCC has been implementing a more forward-looking focus in pursuit of coalition effectiveness. In doing so it is taking account of the following factors:

a. The *full spectrum of conflict in which Coalition operations occur* - from military operations other than war to major theatre war.

b. The *requirement to integrate air, space, naval and land components* into an effective Joint Force with little lead-time.

c. The need to *facilitate rapid decision and execution cycles for expeditionary operations* that may include non-ASCC nations.

d. The likely *deployment of smaller coalition forces*, where individual National contributions may comprise only a few aircraft or a small support element.

e. The *preferred use of non-government and commercial off-the-shelf technology, in place of military specific standards and equipment*.

f. The *rapid development cycles of new or improved technologies*.

Further information may be found at the ASCC website currently at https://www.xo.hq.af.mil/xor/xorg-iso/ascc/. Updates to a public access website should be available by the conference.

5.2 ASCC Purpose.

'To ensure that member nations are able to fight side by side as airmen in joint and combined operations.'

5.3 ASCC Objective.

Through collective agreements, and in cooperation with other international standardisation organisations, members will strive to ensure there will be no doctrinal, operational, technical, or materiel obstacle to full cooperation between the forces of the member nations, and to ensure the greatest possible economy of effort. ***Interoperability in the broadest of terms is the ability of coalition forces to train, exercise, and operate effectively together, in the execution of assigned missions and tasks.*** Within available resources, the ASCC objective of interoperability is achieved through:

- Standardisation
- Validation
- Economical Use of Resources
- Exchange of Information

Standardisation Principles. Standardization is not an end in itself, but is a tool for increasing the operational effectiveness of coalition military forces. Its primary purpose is to achieve specified operational standardisation requirements. International standardization agreements are implemented through national documents that should cross-reference the international agreement.

So what does this mean. Standardisation of design principles, hardware, software, and support systems has the potential for substantially enhancing operational and logistic effectiveness. Standards can promote interoperability, reduce the likelihood of dependence on specific vendors, and promote industrial efficiency through variety control. Consequently these activities have the potential to be conducted overseas against a plethora of potentially unique and even dubious standards and specifications that would require significant redesign and/or qualification to meet an Australian Operational Requirement and expected operating environment. Australia is therefore an active participant in developing and approving standards with our major allies that will significantly reduce such risks before the acquisition of specific technical equipment. Once acquisition is proposed or commenced, all aerospace weapons or stores will be assessed against the agreed standards specified in AAP 7001.054. Therefore for the majority of aircraft stores, AAP 7001.054 is the currently principle Australian implementing document for the IMSA for aerospace including air armament.

Validation. Validation assesses the extent to which ASCC member nations have achieved the specified operational standardisation requirements and focuses on assessing the capability for combined air operations. Validation is conducted through the following activities:

- analysing the lessons identified/learned during operations and exercises
- assessing the relevance, adequacy and effectiveness of existing standards
- confirming that national implementing documents reflect ratified Air Standards
- testing interoperability during exercises or operations

Economical Use of Resources. The ASCC provides opportunities for both formal and informal collaboration on issues of common interest to air forces, thereby sharing successes and avoiding duplication of effort. The following activities may be conducted where they improve national or coalition capabilities, while reducing overall costs:

- the loan of equipment through the Test Project Agreement (TPA) program
- collaborative activities not covered by other organizations
- standardisation of equipment or procedures not directly related to combat operations, where this is expected to result in significant savings and/or improvements to flight safety

Exchange of Information. Formal and informal exchanges of information improve the operational effectiveness of national forces, which in turn enhances the capability of coalition forces. The exchanges also contribute toward ASCC goals by:

- enhancing interoperability where standardisation is inappropriate or where individual national requirements preclude standardisation
- determining the viability of proposed standardisation projects

5.4 ASCC Products

The essence of ASCC endeavours are summarised in the main tangible products of:

- **Air Standards (AIR STDs) and Advisory Publications (ADV PUBs).** The Working Parties develop internationally agreed AIR STDs that are incorporated into each nation's operating procedures. If a document is more of a guide to interoperability, an ADV PUB is produced. The ASCC has some 340 published documents.

- **Information Publications (INFO PUBs).** INFO PUBs are documents that contain information for the prime purpose of exchange between members of a Working Party. The information contained in this publication may be used to support further Working Party activity, but is not of a nature that requires it to be formally distributed as an Advisory Publication.

- **TPAs.** Part of the ASCC Charter allows for the free exchange of equipment between member nations. These loans are for research, development, test and evaluation, potentially leading to standardisation or purchase.

5.5 ASCC WORKING PARTY 20 ON AIR ARMAMENT

In support of these initiatives, WP20 currently has over ten publications in draft on such subjects as: standardisation of stores clearance and test and evaluation procedures; hazards of EMP and lightning; standardisation of air armament flight termination systems; safety criteria for air weapons ranges; and verification of stores interoperability. WP20 delegates have also initiated several new proposals to pursue its standardisation mandate, as defined in the latest ASCC Air Tasking Orders (ATO 2002) at [12]. Their work on aircraft stores self-damage analysis methods will be expanded to include the air-air role. An Advisory Publication will be developed under an existing project to resolve disparities in terminology used to describe the modelling and simulation of aircraft stores clearance and certification. A new project is being proposed to standardise interface requirements for miniature munitions. Such a project will greatly facilitate armament interoperability as these new munitions come into service amongst member nations. A new project is also being proposed to standardise on the design requirements for pneumatic ejector racks. Although these racks will see increased use amongst member nations, there are currently no standardisation agreements to ensure interoperability. This relatively new technology holds the potential for tremendous savings in the logistical tail associated with air armament.

In addition to these "formal" initiatives, WP20 is also expanding its area of interest to include UCAVs, common launcher/carriage systems, a risk management strategy (for armament carriage and employment), interchangeability of chaff/flare consumables and insensitive munitions. WP20 will strive to validate these and other efforts through military exercises, where practicable.

6. AIRCRAFT STORES CERTIFICATION

Weapons should be hardy rather than decorative. *Miyamoto Musashi*

6.1 The Australian Context

The ADF of the future is to be: concept led, capability based – *Joint Vision 2020*, ADDP-D.2

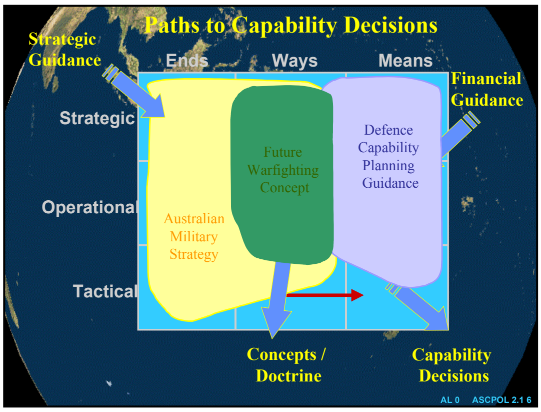
A concept is 'a thought, idea, or notion, often one deriving from a generalised mental operation'

A capability is 'the power to do something'

A capability in the profession of arms is 'the power to achieve a particular operational effect'.

What is it.

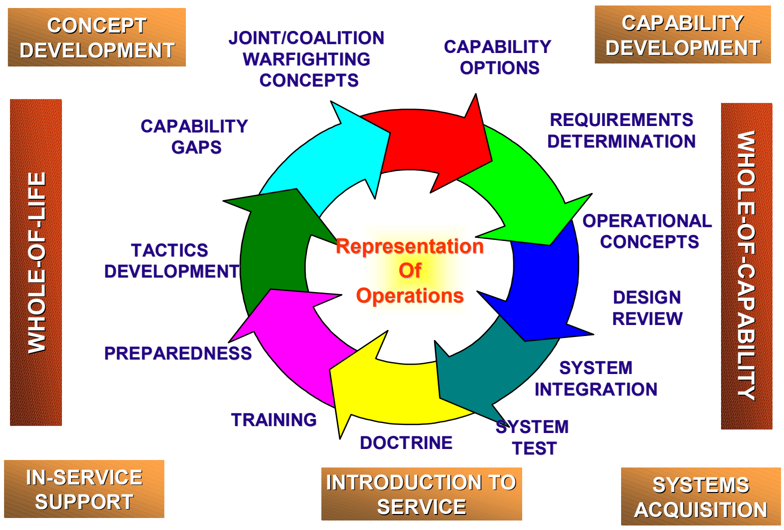
Aircraft Stores Capability. The capability provided by specified aircraft stores configuration(s) certified as meeting approved operational suitability, effectiveness and preparedness criteria.



Aircraft Stores Certification. An engineering, operational and logistics activity that results in the documentation by the Technical Airworthiness Regulators Design Acceptance Representative (DAR) and Operational Airworthiness Authority Representative, or delegates, that specified aircraft stores configuration(s) in the **ASC Flight Clearance** are operationally suitable, effective and that the preparedness status of the established integrated logistics support meets the endorsed Operational Requirement for the aircraft stores capability. Formal approval for authorisation and Release to Service of an aircraft stores configuration is accomplished through publication of appropriate technical orders and manuals.

Application during the systems life cycle.

An overview of the integrated methods by which endorsed operational requirements for an aircraft stores capability are satisfied and the relationship with aircraft stores compatibility is provided in the Technical Airworthiness Management Manual (TAMM) at AAP 7001.067 in the form of a functional flow block diagram and framework for a project involving certification of a 'new'[20] stores capability on a 'new' aircraft diagrams (as shown at Enclosure 1). *The flowcharts at AAP 7001.067 are specifically tailored to suit the* ***risk mitigation strategy and the maturity of the aircraft stores combination being acquired*** *so that analyses and review of existing technical information prevents any duplication of ground qualification or flight tests by the ADF to meet ADF airworthiness and Type Certification needs iaw DI(G) OPS 2-2.* However, to "certify" we need to clearly establish a basis for that certification, ie an Operational Concept…



Initiation of Operational Needs

Any ADF Unit or Element seeking an aircraft stores capability, for either a new aircraft stores configuration, an expanded carriage or employment operating limitations, is able to raise a request for the aircraft stores capability to be certified by preparing an Operational Concept Document (OCD) iaw DCSLCM Manual (2002) and AIAA (1992)[21]. This is shown at Enclosures 2 and 3 wrt the resulting systems engineering activities and the typical capability system life cycle timeline currently expected by the acquisition system for a major new capability respectively!

Such requests are recommended for approval and prioritisation by the appropriate Force Elements Group (ie Air Combat, Maritime Patrol, Army Aviation, Naval Aviation etc) and Commands (ie HQs for Air, Maritime & Land Commands), and endorsed by Director General Aerospace Development[22] through the normal chain of command.

The request for a new or enhanced/modified aircraft stores capability then results in the Acquisition Authority (typically DMO) performing a Requirements Analyses as per ANSI/EIA STD 632 and the INCOSE SE Handbook (2000) at [13]. These requirements are included in the detailed Operational

[20] In the context of this paper a 'new' store or aircraft constitutes one that the ADF has had no previous design disclosure for or has not operated inservice or one that has undergone significant modification.

[21] There is an important principle to be noted here in citing AIAA (1992) for preparing an OCD. The OCDs prepared for Major aircraft acquisitions (ie over $AUD 20 M) may not have sufficient granularity for the air armament being proposed to identify the details required. OCDs for Major aircraft acquisitions will typically refer to subordinate subsystem OCDs that will include the specific air armament needs.

[22] If a significantly enhanced capabilities are being sought in the view of HQAC or AFHQ.

Requirement Document covering such information as described at AAP 7001.067 to establish the specific essential and desirable aircraft stores configurations, operating limits[23] and the associated Critical Operational/Technical Issues and Measures Of Effectiveness required for the capability being sought. Further information may be required than that indicated to justify specific acquisition requirements, however, AAP 7001.067 identifies those issues that historically have substantially affected the airworthiness and the operational suitability, effectiveness and preparedness of the proposed aircraft stores capability. Should particular information not be available, then the introduction of the capability into service may be delayed depending on the cost implications associated with the level of capability being sought.

Even at the early stages of certifying a capability the various agencies (ie the Users in the FEG, DSTO, Joint Ammunition Logistics Organisation (JALO) (the ADFs Explosive Ordnance maintenance and major EO Storage Facility managers), ARDU, ASCENG, etc) should be actively engaged by the Originator to assist in tradeoff studies as shown at AAP 7001.067. ARDU formally addresses this tradeoff by providing assistance in the preparation of the Operational Requirements Document and by preparing a Provisional **ASC Similarity Survey**[24] for the Originator and User of the proposed OCD and ORD. The Provisional ASC Similarity Survey provides an assessment of the certification basis and airworthiness impact in a format that ensures all necessary issues required for the ASC Similarity Survey and ASC Clearance are addressed as early as practicable to reduce the overall cost, schedule and performance risks to the Commonwealth **and** Contractor. Note that the Provisional ASC Similarity Survey does not constitute design certification (from a formal engineering perspective) as it need not be based on full design disclosure of the actual aircraft or store which is ultimately introduced into service. During the early stages of developing aircraft and weapons, limited technical information may be finalised depending on the maturity of the aircraft and/or stores. However, the technical information that is available is used by ASCENG to ensure that the capability certification process is tailored and based on the risk management strategy and the maturity of the aircraft stores combination and the approved Operational Requirement. This has repeatedly ensured that the total cost of the certification effort is minimised (and that a qualitative edge is established).

All **Aircraft Stores Capability Certificates** are based on having an approved Stores/EO Design Certificate, a Safety Case (covering the Safety & Suitability for Service (S^3) for EO), an ASC Clearance and an ILS Plan. Aircraft Stores Capability Certificates are reviewed and re-issued/amended when a 'significant change', as defined at AAP 7001.053 is made to an aircraft stores configuration.

23 See Figure 6a and 6b 4 for scope of an ASC Flight Clearance and an example of an operating envelope respectively showing the carriage and employment limits that will eventually be promulgated in the Aircraft Flight Manual or Dash 1 during ASC Certification.

24 A document summarising the technical review of the aircraft and store documentation to determine if sufficient engineering and test data is available to support an Aircraft Stores Compatibility Flight Clearance by similarity or analogy. If insufficient technical information is available or the data does not support a clearance to the limits requested in the ASC Operational Requirement then the Similarity Survey shall identify the information and testing necessary. The format and content of a Similarity Survey is the same as for an ASC Flight Clearance.

The AAP 7001.067 functional flow block diagram (FFBD) summarised at Enclosure 1 identifies the interactions necessary from all ADF and Contractor activities to achieve an operationally sustainable aircraft stores capability to meet the endorsed Operational Requirement. The efficient progress of the Aircraft Stores Certification effort, be it for the purpose of a Concept demonstration, an OT&E/ Trial or for combat operations, relies on the appropriate agencies undertaking the action(s) required of their organisation and proactively communicating progress and intentions when necessary. These activities are documented in an number or organisations processes that have been repeatedly accredited against ISO 9000[25] for their suitability as a quality management system. All ADF and supporting contractors involved in aerospace engineering activities are required by the regulations in AAP 7001.067 to meet and be independent accredited against the latest ISO 9001:2000. ADF capability management and fiscal processes are being reviewed against Capability Maturity Models such as CMMi (2000) at "Level 3: Defined". Verifying that the *effectiveness* of the aircraft stores capability meets the approved Operational Requirement is primarily the responsibility of the appropriate FEG WSMgr and DMO. Before an **Aircraft Stores Capability Certificate** for particular aircraft stores configurations is accepted for use by a FEG, the WSMgr certifies that safety, engineering, operational, configuration management and logistic support processes, and all training requirements for all personnel involved have been satisfied. The Aircraft Stores Capability Certificate addresses all these issues in a single document for the WSMgrs endorsement. The identification of acceptable ILS arrangements to meet preparedness requirements is the responsibility of the cognizant aircraft and store System Program Offices involved in DMO. Note that the Aircraft Stores Capability Certificate declares the WSMgr and Operational Airworthiness Authority Representatives acceptance that the ILS Plan committing to the capability is adequate to satisfy the effectiveness and preparedness (ie readiness and sustainability) criteria in the Operational Requirement (which is most appropriate as it is the WSMgr who approves the Operational Requirement Document which established the need in the first place).

7. AIRCRAFT STORES CLEARANCE

One flight test is usually worth a thousand contractor promises and analyses. *SQNLDR M.G. Tutty, USAF TPS Sep 1990*

A great pleasure in life is doing what people say you cannot do. *Walter Gagehot*

What is it.

Aircraft Stores Compatibility. The ability of each element of specified aircraft stores configuration(s) to coexist without unacceptable effects on the physical, aerodynamic, structural, electrical, electromagnetic or functional characteristics of each other under specified ground and flight conditions.

Aircraft Stores Clearance. Primarily a systems engineering activity that results in the documentation of the extent of aircraft stores compatibility to safely prepare, load, carry, employ and/or jettison specific aircraft stores configurations within specified ground and flight operating envelopes.

Aircraft Stores Compatibility Flight Clearance. A document issued by ASCENG that defines the extent of aircraft stores compatibility to safely prepare, load, carry, employ and/or jettison specific aircraft stores configurations within specified ground and flight operating envelopes.

Analogy. A form of reasoning in which similarities are inferred from a similarity of two or more things in certain particulars. [Macquarie Concise Dictionary]; or an agreement, likeness or correspondence between the relations of things to one another.

Similarity. State of being similar, a point of resemblance.

[25] See Annex D for a more complete explanation of the ISO agencies and what "ISO" actually means.

Application during the systems life cycle.

What is known as the *systems engineering process* is basically an iterative process of deriving/defining requirements at each level of the system, beginning at the top (the system level) and propagating those requirements through a series of steps which eventually lead to a preferred system concept INCOSE SE Handbook (2000) at [13]. Further iteration and design refinement leads successively to preliminary design, detail design, and final, approved design. At each successive level there are supporting, lower-level design iterations which are necessary to gain confidence for the decisions taken. During each iteration, many concept alternatives are postulated, analysed, and evaluated in trade-off studies. Systems engineering is involved in all steps and *leads* during Mission Analysis, Requirements Analysis, Concept Analysis, and Conceptual Design down into the subsystem level, and *integrates* many other activities including design, design changes and upgrades; Goals & Objectives for element iteration; customer feedback, and operational support. The basic engine for systems engineering is an iterative process that expands on the common sense strategy of:

(1) understanding a problem before you attempt to solve it,

(2) examining alternative solutions (do not jump to a point design), and

(3) verify that the selected solution is correct before continuing the definition activities or proceeding to the next problem.

The basic steps in the systems engineering process are:

- Define the System Objectives (User's **Needs** from the systems level OCD and subsystem level ORD);
- Establish Performance Requirements (Requirements Analysis);
- Establish the Functionality (Functional Analysis);
- Evolve Design and Operations Concepts (Architecture Synthesis);
- Select a Baseline (Through Cost/Benefit Trades);
- Verify the Baseline Meets Requirements (User's Needs); and
- Iterate the Process Through Lower Level Trades (Decomposition)

The context of systems engineering applied at ASCENG in support of major acquisitions, introduction into service & supporting in-service operations is summarised in the functional flow block at Enclosure 1 diagram and the systems engineering process at Enclosure 2 (both from AAP 001.067). Some of the ADF Major Projects ARDU support the DMO with Test & Engineering support can involve over a billion dollars for the acquisition phase. However, even these Major Projects are typically broken down with all the myriad of agencies involved using the systems engineering process into manageable elements and become "small sized projects"[26]. Compared to the wide scope and applicability of ANSI/EIA STD 632 and INCOSE SE Handbook (2000) at [13] to major US acquisitions where a $100 billion initiative can be easily spent for a major systems life cycle, a "small sized project" that ADF acquisition agencies handle the engineering for is typically of the $AUD 100K to 10 Billion size where the support team of Commonwealth and contractor personnel rarely exceeds 10 to 50 personnel (who may all be assigned to multiple projects, of course!). The issue of project size is particularly relevant to weapons where each aircraft stores combination is effectively treated individually and integrated to a common avionics and

[26] Please note that the ADF has no formally agreed SE framework as yet for the whole of defence and DMO especially. The SE discussed here is based on Blanchard (1998) and is being developed in concert with ANSI/EIA STD 632 and ISO 15288. AAP 7001.053 and AAP 7001.067, whilst being primarily airworthiness regulatory in nature, provides the benchmark engineering framework of guidance for Project Design Acceptance Strategy, Type/Technical Certification Plan and Engineering Management Plans which identifies the tailored systems engineering processes to be used.

aircraft structure. The attributes used to tailor the systems engineering process will therefore be derived from experience with such an iterative approach.

As seen at the FFBD at Enclosure 1, ASCENG will provide detailed systems engineering support to the acquisition during Requirements Elicitation/Definition, Concept/Functional Design Review, Preliminary Design Review and Critical Design Review during the ADF's Systems Engineering & Test Requirements Determination phases to reduce risk. AAP 7001.067 ensures that all the authorised engineering organisations with a stake in meeting the Operational Concept have a top level engineering management system framework based on ANSI/EIA STD 632 and Blanchard (1998) that can be easily tailored to the scope of the aircraft stores certification effort being proposed. ASCENG and ARDU, upon receiving a Request for AOSG Support, scopes the range of technical and flying support expected and tailors the project planning activities according to the amount of expected work and conducts a Risk Assessment Model review using all the technical, cost and schedule criteria (developed from the software industry)[27]. The establishment of these business rules are vital to all the potential organisation involved being able to quickly scope out the level of support required in the timeframe and anticipated budget available. The ADF has been successfully halting projects in recent years when the allocated funds patently do not match the performance requested with the expected budget allocations and the level of (im)maturity of the contending systems.

Then involvement by all parties, including representatives of the ultimate User, in the Conceptual/Functional Design Review will commit to an architecture (which may already exist hopefully and be properly systems engineered already!), the Preliminary Design Review is the design-to baseline where we commit to Configuration Item functionality and the Critical Design Review is our build-to baseline that commits us to manufacture. The degree of formality to the design reviews and studies needs to be agreed in the Project specific EMPs especially for all safety critical items (ie anything with explosives in it), based on the experience levels and stability of the organisations involved in the subsystems and similar sized projects. A lot is based on the trust between the organisations involved to keep the Operational Concept for the system and it's associated measures of performance. If considerable personnel turnover is expected then more formality is usually put in place.

Significant Changes. The assessment of aircraft stores compatibility includes review (called a Judgement of Significance) by qualified Design Engineers to determine what impact it will have on the following engineering disciplines for each aircraft stores combination required to determine if a 'significant change' as defined in AAP 7001.053 Regulations at Section 2 Chapter 3 Annex C and MIL-HDBK-1763 is made to an aircraft stores configuration:

- **Fit & Function**
- **Structural & Environmental;**
- **Aeroelasticity;**
- **Captive Compatibility, Flying Qualities & Performance;**
- **Employment & Jettison; and**
- **Ballistics and OFP Validation & Verification, Safe Escape & Safety Templates.**

[27] More on this new model is provided later.

Depending on the *maturity* of the stores and/or aircraft, there are four separate compatibility situations involved when authorisation of a store on an aircraft is required. The four situations, in order of increasing risk (and fun!), are:

a. Adding 'old' inservice stores to the authorised stores list of 'old' aircraft.

b. Adding old stores to the authorised stores list of a new aircraft.

c. Adding new[28] stores to the authorised stores list of an old aircraft.

d. Adding new or modified stores to the authorised stores list of new or modified aircraft.

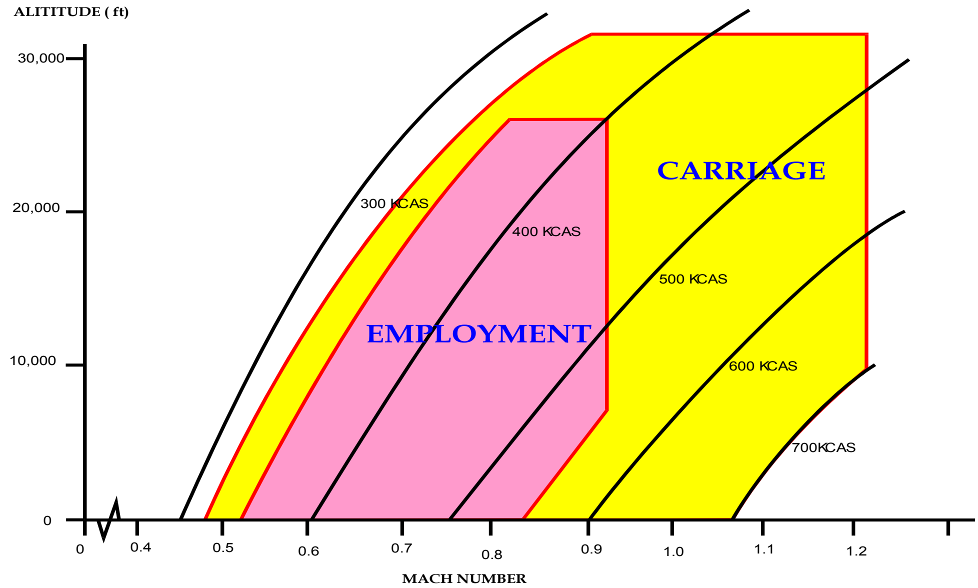


Figure 8. Aircraft Stores Configuration Operating Limitation

For more mature aircraft and/or stores (and consequently those with less risk) the process at AAP 7001.067 is specifically tailored against the OCD and ORD such that only those phases required to be conducted by the ADF to introduce the store into service need to be undertaken. For example, if all the aircraft stores configurations have been successfully demonstrated or certified by known T&E and airworthiness certification agencies to operating limits that satisfy the ADF Operational Requirement an aircraft stores combination could be introduced directly into service with minimal risk.

Using well established 'significant change" criteria and the maturity of the aircraft stores combination, engineering personnel can now integrate the operational requirements against the current EMPs for key system segments and predict the sequence of organisational interactions necessary to optimise the schedule. This will enable the capability to be entered into service and minimise the programmatic risk whilst ensuring the required levels of operational suitability and effectiveness. Although, this is not formalised until after the CDR in an ASC Similarity Survey, experienced personnel realise that selecting more mature aircraft and stores is fundamental to minimising the risk to cost, schedule and performance and the amount of systems engineering required to make configuration management, drawings and publications are made available with the equipment. One very key strategy for defence acquisition in future is for smaller steps to be taken in capability improvement through Pre-Planned Product Improvements (P^3I) and a spiralling concept throughout the systems life to meet changing needs and

[28] Or adding new aircraft stores configurations and/or expanding the flight operating envelope.

OCDs, especially for avionic systems where computing power improvements clearly outstrip the traditional defence acquisition processes.

The success of such a strategy to establish clear baselines with tolerances for "significant changes" to control the update and amendment of extant ASC Engineering Data Packages and the associated ASC Clearances is fundamental to the order of magnitude increase in new aircraft stores combination being cleared by the ADF as a result of the ADF deciding to update aircraft OFPs and the acquisition of ADF unique aircraft stores configurations. During this process it is important to ensure adequate integration between aircraft and store inservice Authorised Engineering Organisations is undertaken by DMO to ensure a whole of system approach is maintained and DMO short sightedness is tempered appropriately to support the sustainment phase. This will ensure that either the aircraft or weapon sub systems are not traded off or compromised without input from all parties. If required to achieve this, ASCENG will conduct such reviews if not planned in the ADF Project Design Acceptance Strategy already to ensure the whole of systems approach is maintained throughout the life-cycle.

As engineered systems became more complex and include multiple software and personnel interactions, engineering disciplines and organisations sometimes became fragmented and specialised in order to cope with this increasing complexity. Some organisations focused on the optimisation of their products and often lost sight of the overall system. Each organisation perceived that their part must be optimal, using their own disciplinary criteria, and failed to recognise that all parts of a system do not have to be optimal for the system to perform optimally. *This inability to recognise that system requirements can differ from disciplinary requirements is a constant problem in major systems development.* The systems engineering process can be viewed as a major effort in communication and management of complex teams of experts that lack a common paradigm and a common language. Two of the vital tools that a systems engineer needs therefore to be able to conduct appropriate:

- **Experimentation & systems modelling** at the necessary level of fidelity across the broad range of engineering and programmatic disciplines, and
- **Risk management** of all the constituent elements of the system.

Not only are these tools vital to the ultimate systems performance and safety in it's use but they are two of the most commonly misused terms[29] and sources of "activity traps" if used inappropriately or in the place of positive management and active decision making for the system, its subsystems and for the super-system that it belongs to.

8. SYSTEMS MODELLING

All models are wrong, some are useful.	*Engineering Axiom*
The man who insists upon seeing with perfect clearness before he decides, never decides.	*Frederic Amiel*
A first-rate theory predicts, a second-rate theory forbids and a third-rate theory explains after the event	*Alex Kitiagorodski 1975*

What is it

The fundamental terms and the major issues affecting the valid modelling of a system INCOSE SE Handbook (2000) Sect 4.3.1.4.4.6, that support the extensive recent literature such as at Blanchard (1998), Cloudy & Rainey (1998) and SI (AOSG) OPS 4-33 are:

Model – *Any representation of a function or process, be it mathematical, physical, or descriptive.* They are typically of two categories – representations (employing some logical or mathematical rule) and simulations (which mimic the detailed structure of the system and may include representations of subsystems or components) that may be made up of one or several of: physical, graphical, mathematical (deterministic) and statistical (probabilistic).

[29] Probably even more so than systems engineering itself!

Simulation – *A computer program that represents the operation of a function or process to the degree of accuracy necessary to meet its purpose.* Typically realistic or representative scenarios are run in the time domain to simulate the behaviour(s) of the proposed or real system.

Fidelity – *The degree to which a model realistically represents the system or process it is modelling* – not necessarily the level of granularity, detail or complexity of the model.

Level – The typical differences in fidelity, intended use, types of resources and commitment, from low to high are[30]: 0 - Math Constructs, 1 - Computer Simulations, 2 - Hybrid Models, 3 - Virtual simulations, 4 - Distributed Model Networks, and 5 - Live Exercises[31].

Validation - *confirms that the system, as built, will satisfy the user's needs* – ensures that "you built the right things".

Verification - *addresses whether the system, its elements, its interfaces, and incremental work products satisfy their requirements* - ensures that "you built it right".

By constructing a model, at any of the above "levels", one hopes to gain *sufficient confidence* in the success (or lack of failure for the safety people) of the initiative by obtaining timely information about the proposed or current system before committing significantly greater resources to the systems development, design, integration, qualification test, manufacture, operation and disposal. The information sought necessarily must cover the breadth of cost, schedule and performance issues - which should determine the thoroughness and completeness required of the requisite models. Models are especially important in simulating performance of novel systems in harsh or hazardous environments that may affect user and/or public safety for example. *They are also vital for understanding system performance when non-linearities, time critical or counter-intuitive behaviours are known to be present.*

Models and the simulation of representative scenarios are one of the most significant and comprehensively used risk reduction tools available when used judiciously (with more detail being discussed in Risk Management at Section 9). This is not only important to fellow scientists and engineers but also to non-technical project managers and end-users to answer their key questions on Critical Operational/Technical Issues and impact on cost/schedules.

In practice, the most powerful models are those that can evolve with the system and can then be reused with greater confidence and lower risk on future systems. Some models can in fact become stand-alone products of themselves. This is particularly relevant in the higher level models. One side benefit of the latter situation when the model becomes the product is the reductions in cost of having multiple versions of software that need to be configuration managed and undertake V&V when modified. Today there are numerous examples of software code models being developed becoming one of the final product deliverables.

Application during the systems life cycle.

Those who implement the plans must make the plans. *Patrick Haggerty, Texas Instruments*

Systems modelling and simulation for complex or safety critical systems must be established and maintained throughout the whole of life – from lust to dust[32] as shown in Enclosure 1 showing a typical life cycle up until disposal. In the pre-acquisition phase the efforts will be focused on understanding a current system and any reported deficiencies in performance or may be on exploring new concepts and trade-offs between technology that may be in or under development. If one is particularly lucky there may be validated and verified models that can confidently address all the areas of the cost, performance

[30] See INCOSE SE Handbook (2000) Fig 4-64 for a more complete description.

[31] These levels are virtually synonymous with the level of Simulators that can also be one of the end products for training users of the system in it's operation!

[32] The 'Cradle to Grave' concept so beloved by the logistics fraternity starts too late (conception has already occurred!) and finishes too early (the environmental impact may not be over yet!).

and schedule of the existing system or one that is very similar that can provide meaningful (and reliable) data and/or information that is compatible and of the correct granularity with the modelling environment being used for the proposed system. The models must recognise adequately the scope of affected systems and subsystems and anticipate sensitivity to cost or schedule overruns on the super-system.

As Thambain (1992) notes, this strategy may engender considerable conflict early in the project. However, if adequate funds and schedule are not forecasted by the models based on contemporary projects of similar magnitude and safety criticality and not implemented then the proposed system or project is almost certainly doomed to failure – even before conception is consummated! In fact the "risk consideration by program phase" of INCOSE SE Handbook (2000) Figure 4-33 graphically illustrates the risks that the system models should be considered for modelling as a project progresses from earliest planning through to disposal with less surprises. Finally, Elliot (2000) has come to make the conclusion that there are:

- **Simple decisions** where you know what it is you are trying to achieve and the difficulty is in achieving it, which have two sorts of errors (ie efficiency or effectiveness - where you can almost choose which error you prefer), whether you can actually analyse the problem and whether it is worth it to do so;
- **complicated decisions** where it is not even obvious what a good solution looks like; and
- **complex decisions** where the perverse behaviour of systems means that your decisions can only be made in light of other decisions.

The implication of this is most pertinent to any systems modelling when there are assumptions, metrics and values of the Originator and Users Operational Concept that may (will) be open to interpretation. Even simple decisions & solutions are often difficult enough to a large acquisition organisation and you still have an acquisition system with a myriad of personalities and agendas to address and 'help' with the complex decisions. It doesn't sounds like a "cunning plan" to not have any guiding document from which to derive Operational Requirements from and ensure the acquisition system pays for! Therefore systems modelling can also explore the assumptions, metric, values and the sensitivity of the Operational Concept to potential weaknesses and thereby simplify the decision making process. In doing so one must not forget:

Systems modelling can be one of the fundamental analysis methods available to help shape the future with some greater confidence and rigour.

The future is not some place we are going to, but one we are creating. The paths to it are not found, but made. The making of these paths changes both the maker and the destination.
Peter Ellyard

9. RISK MANAGEMENT

A ship in harbour is safe - but that is not what ships are for. *John A. Shedd*

What is it

Risk is potential harm to the project or system under development. Although there are numerous related standards and texts in the literature such as AS/NZS 4360: 1999, Cook (2002), MIL-STD-882 and Blanchard (1998) et al, the fundamental terms and major issues affecting the risk management of a system as per INCOSE SE Handbook (2000) Sect 4.2 at [13], are:

Risk – *A measure of the uncertainty of attaining a goal, objective, or requirement pertaining to technical performance, cost, and schedule.* Risk has two components – the **likelihood** (ie the probability) of an undesirable event will occur and the **consequence** of the event if it does occur.

Risk Management – *the recognition, assessment, and control of uncertainties that may result in schedule delays, cost overruns, performance problems, adverse environment impacts, or other undesired* *consequences.* Balances the level of acceptable risk with the potential rewards. Addresses uncertainties in both products and processes. Program & Environmental risk management have different objectives and require different methodologies. The framework must be developed with processes and methodologies that suit the best practices of the industry involved and the scale of the project or system being considered.

Acceptable Risk. A predetermined criterion or standard for a maximum risk ceiling which permits the evaluation of cost, national priority interests, and a number of tests to be conducted. Numbers of events and exposed numbers of personnel are essential in deriving this.

For Australia, AS/NZS STD 4360: 1999 identifies the iterative process designed to support better decision-making. This standard recommends a six-step management process that parallels INCOSE SE Handbook (2000) at [13] to quantify the cost of doing business in the broadest of contexts rather than having 'risky management' as cited at HB 142-1999. Furthermore, the Commonwealths *Occupational Health and Safety Act*, 1991 Sections 18 and 19 specifically refer to the duties of Manufacturers and Suppliers in relation to Plant and Substances to ensure that all goods and written instructions are provided in such a condition as to be safe and fit for use in Australia.

Within defence and related industries, MIL-STD-882 has for some considerable time established the benchmark framework for assessment and management of risk from systems safety perspective during all acquisition and in-service operations for ground, sea, air and space operations. It provides a consistent means of evaluating identified mishap risks so that they can be evaluated, and mitigated to a level acceptable (as defined by the system user or customer) to the appropriate authority. System integrity levels are established using MIL-STD-882 as a basis for System Safety Programs involving safety critical systems. The acceptance levels for the identified risks are usually assigned for "through life" (ie for T&E and in-service/combat operations) based on the significance and the consequence of a probable event to streamline the decision making process. Tailoring of the MIL-STD-882 Safety Program is undertaken to balance the cost incurred and the benefits to be gained from establishing a tailored version of the standard to suit the specific needs of the program. Design Assurance Levels (DAL) (see Enclosure 4 for details of this from RTCA DO-178B) need to be identified to establish regression testing (unless demonstrated competence from a contractor on a similar type of system complexity & criticality) warrants the lowering of the DAL and hence the cost incurred to the project.

As risk is the potential harm to the project or system under development, all stakeholders in the system or processes delivering the system must all be deeply concerned with the potential adverse impact of the technical, cost, schedule and programmatic sources of risk. Risk management strategies need to be developed and approved to support the assessment and positive management of risk and support a rationale decision making especially for complex or safety critical systems. Although ANSI/EIA STD 632 6.1.2.4 Note 2 highlights that risk management requires discipline, risk management is useful only to the degree that it highlights the need for action, and that action leads to the problem(s) being addressed quickly and thoroughly.

Application during the systems life cycle.

Now, there are two ways of learning to ride a flying machine; if you are looking for perfect safety, you will do well to sit on a fence and watch the birds; but if you wish to learn you must mount a machine and become acquainted with its tricks by actual trial.

Wilbur Wright, Miracle at Kitty Hawk

Risk management needs to be continuously conducted throughout the system life cycle. As noted in ANSI/EIA STD 632 things can go wrong right up until the last phase of the project is completed. Since the last phase of a project should be its disposal, failure to address the risks may have long lasting dire environmental or remediation consequences. The major challenge of risk management though is not to just focus on failures, but to attain a proper balance between risk and the benefits or reward. Without a reward, the identified and implicit risks (those risks that result of undertaking a potentially hazardous operation/activity which may not have been identified adequately) should be ameliorated, avoided or transferred appropriately. All personnel involved in the operations of the project/system which may be hazardous must be fully engaged and understand the informed hazards and need to be in agreement with who is accepting what degree of risk to achieve the reputed reward.

The Risk Management Plan for the Project being implemented needs to describe the project aspects of risk identification (sources and causes), risk characterisation (effects, probabilities, choices, time frame and coupling), risk prioritisation (greatest harm, effect and time urgency) and risk aversion (mitigation, avoidance, transfer, and acceptance). It identifies the risk management functions to be performed by assigned teams and supporting personnel. The acceptable levels of risk for a particular life cycle phase need to be included and then updated as the life cycle matures and the identified level of risk change – in some cases allowing funding to be redirected to improve other areas and in some cases to address changed circumstances or indeed to rectify new hazards. One after all must remember that systems comprise various assignments of products, processes and people and all three are continuously changing – so too must the risk management framework. The only time to really worry is when it is reported or alleged that no changes are warranted to the system! It has probably then become complacent or inefficient – and that in itself warrants application of risk management.

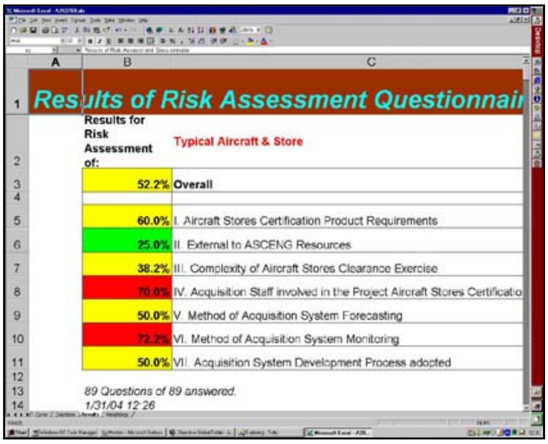


Figure 9. Sample ASC Flight Clearance Risk Assessment Model result - see Enclosure 6

To address this situation a Risk Assessment Model was developed by ASCENG with the University of SA based on the work for the software industry by Say-Wei Foo and Arumugam Muruganantham (2000) tailored to aircraft stores clearance activities covering seven contributing project risk elements all considered to be major factors for the success of any ASC flight clearance task. A risk model based on the software industry was intentionally selected as software now poses the highest risk to cost, schedule and performance of all the systems engineering activities. The project risk elements recommended by Savvides & Fitzgerald (2002) have been developed and are shown at Figure 9. Figure 9 also provides an example of the results from questions that are posed to establish the risk profile under each of these elements. (The complete questionnaire is at Enclosure 6.) As this is an initial quick look risk model, a straight forward three level response system has been devised until greater fidelity can be established later in the project. Several DMO Projects have assessed using the model (see Figure 9) and an electronic questionnaire that will be investigated further for usefulness and utility[33]. Comments are invited on the methodology and the scope of the questions at Enclosure 6.

[33] Of interest is that the ASC Flight Clearance RAM example in Figure 9 was completed for the aerospace component of the Joint Project 2070 which involved mines being purchased for air, surface and sub-surface delivery. The model correctly predicted medium levels of risk for the complexity of the air delivered segment of the Project as the aircraft stores capability 'Detailed Operational Requirements Document' was adequately quantified. The JP is on indefinite hold however until a more mature mine that meets all the air, surface and subsurface delivery methods is available at reasonable costs.

However, useful the ASCENG RAM has, and will continue to be, for working with DMO and the FEGs, ASCENG needs a simple tool to be able to better compare and contrast the different maturity states of aircraft and stores. Such a tool needs to be able to visualise the risk reduction by the acquisition of prior testing information during the project, especially during the T&E phase obviously, to better determine schedule drivers against relative risks.

Aircraft Stores Compatibility Risk Assessment and Tracking Model

The ASC Risk Assessment & Tracking model has been written in Excel © ™ to provide a simple risk assessment and tracking tool that can be used by engineers to address all the aircraft stores compatibility disciplines in AAP 7001.067 and Figure 3 as well as track the MIL-HDBK-1763 tests conducted to reduce risk and gain confidence in performance levels. As shown by Tutty (2003) at [4], Lockheed Martin Aeronautics Company (LMAC) has developed a tool that was the genesis of applying the concept to replace the extant ASCENG process in determining the 'Judgement of Significance'; more on this later. The LMAC version at Figure 10 shows the risk reduction and milestones proposed for a simple program involving a limited number of major events from the Aircraft Critical Design Review and the conduct of separations testing iaw MIL-HDBK-1763 four to five years later.

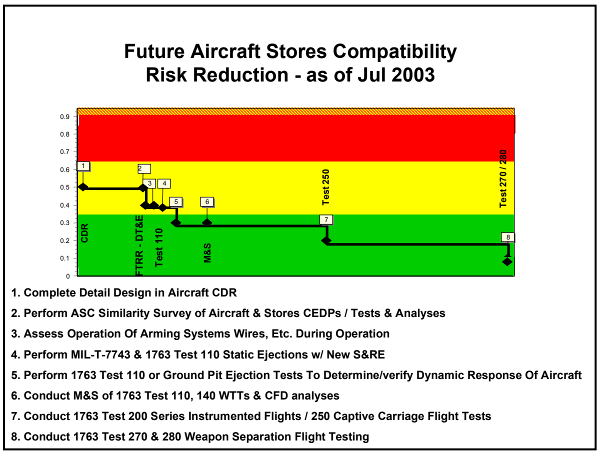


Figure 10. Proposed Risk Reduction Programs - courtesy LMAC

The ASC RAT (included at Enclosure 8) has the following major attributes going from left to right on the '***ASC Input Risk Assessment'*** Page:

- Each of the seven major ASC engineering disciplines are identified and are then broken down according to AAP 7001.067 to the supporting discipline. Invariably a project moves from the fit and function disciplines to inflight ballistics testing as a matter of course to significantly reduce safety and costs. This is sequence is based on the authors experience with successfully leading the US revisions of MIL-HDBK-1763 and clearing over 700 aircraft stores combination with 20 different aircraft types (and 50 models/variants) and over 175 stores/weapons types(and some 400 model/variants). Note that 'Procedures V&V' has six supporting disciplines identified which are the major publication required for certification, namely the –1 Aircraft Flight Manual, -32 Weapons Preparation Procedures, the –33 Weapons Loading Manual, -34 Aircrew Weapons Preflight & Inflight Procedures, -1-2, the Aircraft Preflight Checkout Procedures and –2-11 Aircraft. These are identified separately to give additional weight to the risks associated with NOT getting publications to train and qualify people in the use of the equipment properly and safely.
- The 'Consequence' of the identified risks are then addressed with Criticality, Design Assurance Levels, Performance, Cost and Schedule factors having default typical values that may be changed to suit the maturity of the aircraft stores configurations before a 'Maximum Result' is flagged.

- Probability has the 'probability of failure' coming from Failure Modes & Effects Analyses and the like being modified with 'Maturity', 'Complexity' and 'Dependancy' Factors before an overall resulting 'Risk Factor' is calculated. Note the INCOSE (2000) criteria have been used as discussed in depth by Tutty (2003). In the columns for Maturity, Complexity and Dependency an aid for the user has been added for them to select values from 0 to 1 for systems going from 'old' to 'new', 'simple' to 'complex' criteria respectively as these were found to be very useful.

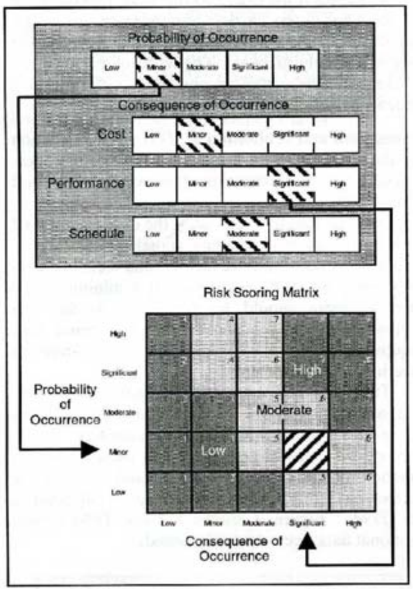


Figure 11. Recommended method for determining Consequence - from (Donnelly (2000)

- The 'Risk Factor' is then calculated for each discipline and is hence a 0 to 1 based value.
- As a project moves through its major systems engineering phases, analyses and testing at the system and subsystem levels will be conducted. MIL-HDBK-1763 has a standardised series of ground and flight tests that are used to enhance the interoperability of test data between services and nations. These are used in addition to newly identified Modelling and Simulation analyses (numbers with the leading '0' – which are being implemented and trialled at ASCENG & ARDU over the next 3-5 years as part of AAP 7001.067 before recommending changes to MIL-HDBK-1763) to reduce the identified 'Risk Factor' for that discipline. As noted in the '*ASC RAT User Guide' Page*, the assumption has been made that for each discipline which typically has an analyses, a ground test (numbers with the leading '1') and a flight test (numbers with leading '2') identified that the risk reduction is equally spread between these items. If the specific analyses or testing has already been conducted and reported then the Probability columns should reflect commensurately high scores for maturity and complexity and extremely low probabilities of risk. Then, most importantly, the date that the analyses and testing is completed and a test report is provided is then identified.
- Some straight forward calculations are also provide on 'Risk Factor' to indicate average and maximum values. This method, which is similar to use of Figure 11 and 'Technology Readiness Levels' gives extremely high 'Risk Factors" due to the use of the probability rules associated with so many sub-disciplines in this model. For the Risk Assessment to not be EXTREME for most aircraft stores compatibility project required use of existing technology or there being no risks in technology and schedule, which is unrealistic.

As shown at Figure 12 the ***normalised risk profile*** for what starts off as an extremely high risk exercise (ie no prior analogous engineering or test work) with a tight (and for the purpose of this exercise a linear timeline has been assumed) schedule of all activities is illustrated. Note the addition of a red 'Trend-line' (an Excel 6th Order 'Polynomial fit' is shown in these figures) and error bars (an Excel standard error band) are automated. Note that the final V1.0 model has the Trend-line included as a 'Moving Average' of 'Period 2' as a better representation of more typical projects that would be of utility to users. There are also other cosmetic colour differences incorporated to enhance the input table and the output Tracking Charts as well.

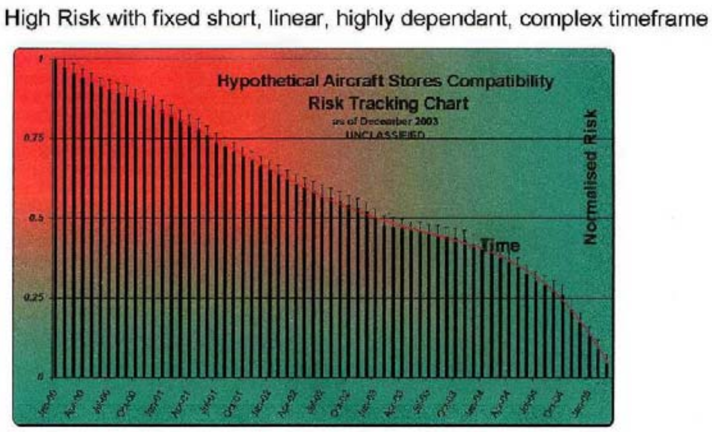


Figure 12. ASC RAT Risk Tracking Chart

The example as Figure 13 is probably therefore a more representative profile - wherein there is available prior engineering and testing having been done already and the Australian analyses and testing are being done in quite distinct (and obviously non-linear) phases. This more closely approximates the LMAC risk reduction tracking chart with some sixty five risk factors now being covered in the tool.

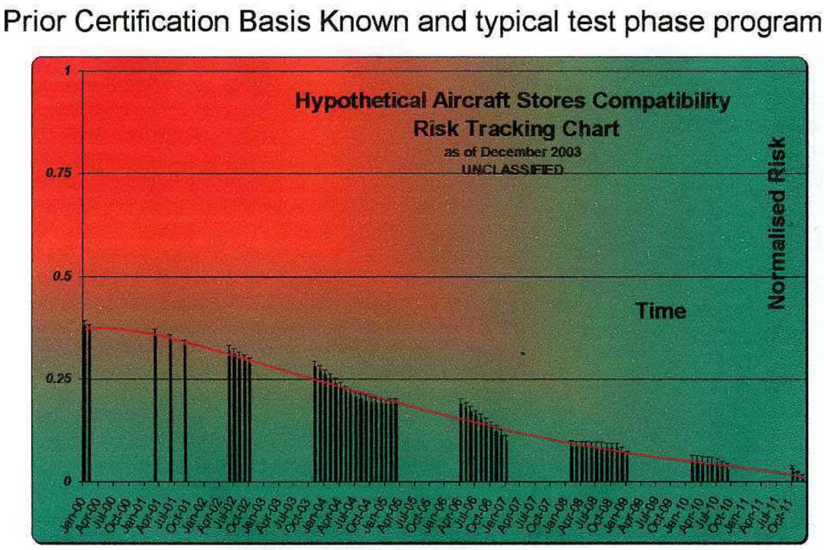


Figure 13. Example of a more representative ASC RAT showing effect of prior analyses and testing having been conducted for a Medium Risk project

The concerns expressed by Conrow (2003) in general and by the author in Tutty (2003) about the use of normalised curves is particularly applicable here. Furthermore, some risk profiles are hidden in the number of major issues being addressed: and all of them with some risk (which serves to make Director ASCENG's job more fun)! Note that the typical 'drop-off' feature at the tail-end of the plot is not present as in all the other examples provided due to all the required Procedures being assumed to be available in this case at low risk. Provision of Procedures has been modelled to be almost 20% of the normal traditional risk.

10. THE FUTURE

It is a shameful thing to be weary of inquiry when what we search for is excellence. *Cicero*

The Process Versus Product Debate

The essence of the problems with acquisition world wide seems to be in the detail needed to capture the complexity of Users' Operational Needs versus the Sponsors wants. Who hasn't been trapped in interminable integration meetings with seemingly multitudinous software engineers who haven't been appraised of the Operational Need and may not even be domain specialists in industries such as aerospace. With the pervasive use of ISO 9000: 2000 quality management processes and Capability Maturity Models, it has been noted by Mackey (2000) that product and process engineers seem to have postures, assumptions and behaviours reflecting the planetary divide between gender based cultures. According to Gray (1992) men are most like product engineers[34] and act as if they are from Mars and women are most like process engineers [35] and act as though they are from Venus.

With this in mind, who hasn't heard the following during a Preliminary Design Review 'We've already started coding the easy stuff and we can design the rest as we go' vice 'I know this is short notice, but can we schedule an ISO audit next week'! Whilst all companies may depend on both groups contributions, most companies cannot exist without products. The contribution of process engineers is not usually as self evident. However, the process engineer will not typically just fix the flawed product, but will also fix the process that allowed the flaws into the product so you wont have to keep fixing such problems in future products. The proactive process engineer who wants to contribute meaningfully to achieving a company's outcomes needs to focus on improving areas that have real significance to the developers as opposed to instituting more bureaucracy…

Teams with good leadership and management with a highly disciplined engineering process such as that discussed in Filmer (2001) will not only improve product quality but will actually improve their time to market. Filmer (2001) provides a seminal discussion of the Systems Engineering processes instituted at ARDU using Blanchard (1998) for developing and approving ARDU Non-Standard Modifications (NSM). The examples cited in Filmer (2003) exemplifies how a highly disciplined engineering process can successfully deliver high integrated technology products in the aerospace environment. The shorter "time to market" characteristic has also been found to be applicable to aircraft stores compatibility.

The belief of Jumper (2000) that "`The product is more important than the 'process'` is almost an axiom at ASCENG. If you can get the operational requirement, product and methods right, suitably tailored processes will then usually follow.

Australia is committed to implementing a fully integrated framework in AAP 7001.067 that encompasses requirements definition, acquisition, Explosive Ordnance, experimentation, T&E, systems safety, weaponeers and inservice logistic cultures that focuses on communication of agreed products. No small ask when no aircraft or air delivered weapons are designed or manufactured in Australia.

[34] This includes software developers and development managers
[35] This includes software quality engineers, process improvement specialists and change agents

Each nation in ASCC have also been collaborating on their products to identify equivalence of acceptable airworthiness, T&E methods and safety systems wrt aircraft stores clearance and certification: the USAF with Certification / Clearance Recommendations, USN Flight Clearances, UK Military Aircraft Release, etc. The application of clearly identified national joint processes amongst the allies has however been far more problematic. As all three services in the ADF have been directed to use joint airworthiness processes that establish a common framework that can now be used to gather performance information as to the success of tailoring the process based on the maturity of the aircraft stores configuration so as the right product is delivered by all the required agencies in a co-ordinated fashion.

EIA Interim STD 632 has been cited for use by AAP 7001.053 since 1995 and it has been agreed that ANSI/EIA STD 632 should be used as the ADF SE framework. All future Originators seeking new or significantly enhanced aircraft stores capabilities are to have an Operational Concept generating an Aircraft Stores Capability Operational Requirement which, as a minimum, will provide the information iaw AAP 7001.053/068 and its successor AAP 7001.067. To refine the Operational Concept, before finalising the ORD, more Concept Demonstrations are being conducted by the ADF, often with support by DSTO. In recent years ARDU has been conducting Concept Demonstrations including: flight trials of Raytheon's EO Sensor in the UK DB-110 pod (a Tornado fuel tank with a $US 6 Million seeker relying on a hardback designed for UK stores suspension equipment which does not comply with MIL-A-8591) on F-111C aircraft during exercises in Northern Australia, Python IV and an ASRAAM prototype from the F/A-18 (in support of Project AIR 5400), the US MK65 mine from the P-3C Orion with a new Target Detecting Device, the Leigh Aerospace LONGSHOT Long Range Extension Kit from F/A-18 aircraft (both in support of Joint Project 2045), as well as flying the Australian designed INGARA Synthetic Aperture Radar and APG-73 Hornet Radar, and the US Small Smart Bomb from F-111G weapons bay (now the GBU-39 Small Diameter Bomb), et al. Further details of ARDU capabilities are beyond the scope of this paper but are documented at the unclassified level at Tutty (2003).

To rectify the previous deficiencies in providing the ASC Engineering Data Package information, full 'Design Disclosure' of all issues affecting Technical and Operational Airworthiness is to be made iaw with AAP 7001.067 documenting the maturity of the aircraft and/or weapon and all testing that has already been undertaken. Although a Risk Based Approach is being developed for applying this, the contractor should expect to be held liable for conduct of any requalification if it is subsequently found that the weapon/stores system fails criteria that were agreed in the OCD and ORD.

How can one avoid the current aircraft integration nexus and black hole in funding? One solution highlighted at Tutty (2001) at [4] is to not integrate the weapons system via the aircraft avionics at all. ARDU has conducted successful flight trials of the Leigh Aerospace LONGSHOT Long Range Extension Kit where an electronic knee pad could be used to control programming of weapons via an RF data link - thereby avoiding the aircraft avionics integration 'black hole'. If the RF link is of short distance and limited spatial orientation then there should not be any operational impact. This also has relevancy to the limitations on the aircraft Bus Traffic and memory available in the aircraft avionics. The aircraft OFP and bus can handle a finite amount of data transfers.

With the down sizing of the aircraft avionics industry to one or two players the strategy of MIL-STD-1760 needs to be reassessed to ensure that these players are not establishing a monopoly and that ruggedised commercial interface standards would not be more appropriate. The collaboration of the US DOD with the Society of Automotive Engineers (SAE) to develop some of these standards is an outstanding initiative to help prevent such a monopoly for the interface designers from the weapons perspective. One needs to remember that a lot of the weapons we are testing today have significantly great processing and computing power than the host aircraft. Therefore there needs to be greater consideration to where processing needs to be performed and whether that processing is safety critical and hence the interface design requirements.

Recent Initiatives

ASCENG has also instituted a number of measures to address the lack of a systems engineering framework during acquisition. These include:

a. Mandating complete air armament system design reviews in AAP 7001.067 iaw ANSI/EIA STD 632 and MIL-STD-1521B[36] and instigating such Design Reviews under ASCENG's auspices if the complete system has not been adequately addressed.

b. The ADF will continue to monitor development of the ISO 15288 Systems Engineering Standard for its applicability to aerospace operations.

c. Consistently promoting the use of logical decision making milestones to ensure that engineering activities are tied with experimentation, T&E and capability milestones so that all the myriad agencies involved understand better their criticality and involvement.

d. Revamping the training being provided by ASCENG in the ASCPOL and ASCTECH Handbooks with introductory lectures on Systems Engineering and Safety to better *describe* the requirements *prescribed* by AAP 7001.067.

e. Setting a vision of ASCENG being compliant with CMMi Continuous Model "Capability Level 3: Defined" by being ultimately compliant with "Capability Level 5: Optimizing" and assisting with other ARDU improvements to be "Capability Level 4: Quantitatively Managed" by 2007! This will ensure ASCENG is prepared in it's own time for when such a requirement is probably eventually made internal to defence mandatory (at Level 3 we suspect at least) as DMO is insisting its external customers are similarly compliant (as occurred with implementation of ISO 9001). ASCENG also intends to monitor the commercial standard on CMMi as it potentially transitions to being an ISO standard to determine suitability of compliance for future development of ARDU and ADF/ASCC capabilities. DMO should also continue to develop procedures that would be compliant with CMMi "Level 3: Defined" when the DCSLM Manual is published.

f. Developing and implementing a physics based scientific method for armament test activities to be written iaw ISO 17025 and Bock (2001).

g. Interoperability of UAVs has an IPT formed which will address the CONOPS for activities such as at Figure 12 a and b. Dr Anthony Finns recent comment at the DSTO Automation of the Battlespace Workshop on this on the 6th May is most relevant:

> A US styled UAV system that needs over 70 personnel to operate it, is not "Unmanned"!

h. Integration of Air Armament Mission Planning and use of US Theatre Battle Management Core Systems (TBMCS) for integrated planning using MIL-STD-3014 PGM Data Files philosophy (see Figure 14) for Modelling & Simulation for DSTOs 'Battlemodel' and MSTARS, Performance & safety template generation.

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[36] Despite the letter being tailored more to just Software Engineering products, this STD is still cited/preferred due to absence of any Australian or more Systems Engineering consistent documentation to achieve the same purpose as yet.

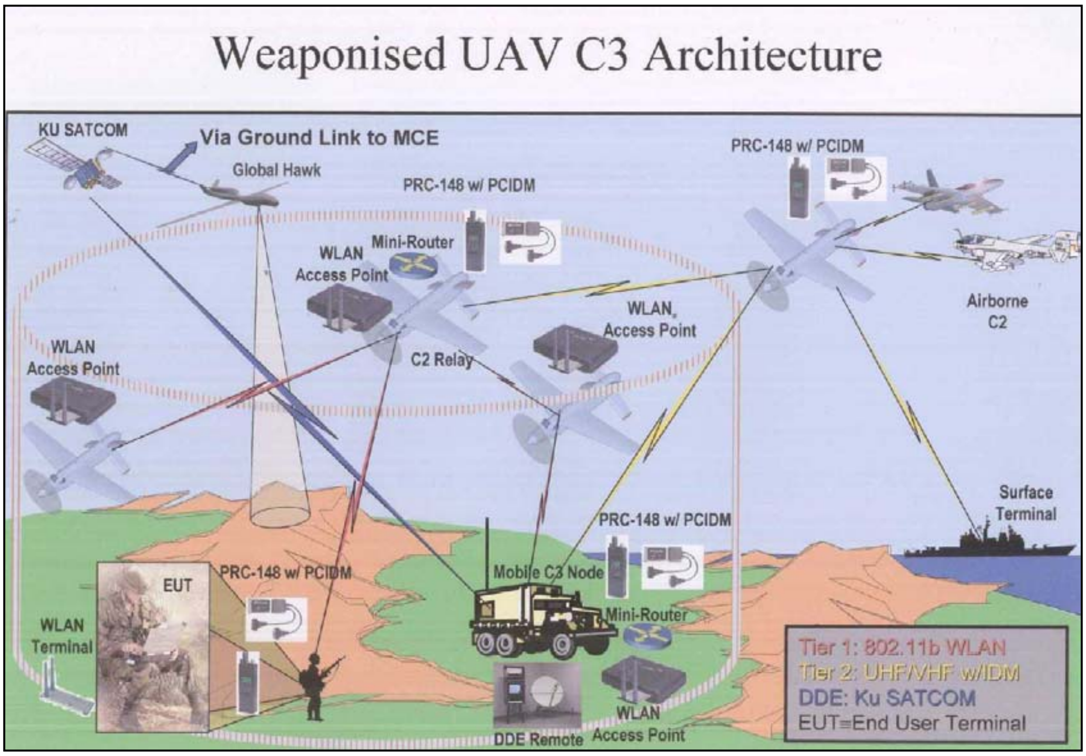


Figure 13a. Weaponised UAV CONOPS

Figure 13b. The UAV's UAV Mothership – from IDR

i. **Weapon Data Link Architecture (WDLA).** [16] has publicly announced that 'The USAF has awarded Rockwell Collins a contract on 10 Oct 2003 to lead a WDLA program. The contracts $23.4 million ceiling is for the development of networked in-flight communication for precision guided weapons, using Software Communication Architecture (SCA) that is compliant with the [US] DoD Joint Tactical Radio System policy. The first delivery order under this contract is valued at $5.35 million. Rockwell Collins will be the prime contractor leading an integrated product team to develop a scalable architecture. The program, previously known as Banshee[37], is under development for the US AF Research Labs. JTRS is an open architecture, software-programmable radio system

37 Very interesting project name now used in the open literature by IDR, Janes, et al. The *banshee*, from ban (bean), a woman, and shee (sidhe, a fairie), is an attendant fairy that follows the old families, and none but them, and wails before a death. Many have seen her as she goes wailing and clapping her hands. The keen (caoine), the funeral cry of the peasantry, is said to be an imitation of her cry. When more than one banshee is present, and they wail and sing in chorus, it is for the death of some holy or great one. From www.yahoo.com. Obviously, this harks back to the days when codenamed projects had the name for some intellectual or more prurient reasons rather than off some pre-determined, boring list!

that will be adopted as the joint service standard for all new tactical communication systems. ***The WDLA implementation will enable secure, mission-specific communication protocols and parameters to be reprogrammed in minutes.*** The first delivery order of the program includes development of requirements, architecture design and validation for a scalable 50-cubic-inch weapon datalink. ***Future delivery orders will include a complete architecture design and verification of a 10-cubic-inch, multi-channel weapon datalink, using SCA-compliant waveforms and integrated in precision guided weapons***. The program will utilize and expand upon design elements leveraged from ongoing Rockwell Collins development activities, including Tactical Targeting Network Technology, Crypto-modernization and JTRS.' The development of the WDLA will be done in close collaboration with ASCC and NATO standardisation.

j. **NATO Air Armament Working Party and SAE Fuze Interoperability Studies.** In an initiative that will also serve to address the lessons re-learnt from Figure 2, the US Society of Automotive Engineers, NATO AAWP and ASCC WP 20 are collaborating on better fuzing architectures as shown at Figure 15.

k. Seeking consensus of ASCC and TTCP nations to national approaches to above in applying methods especially for M&S environment.

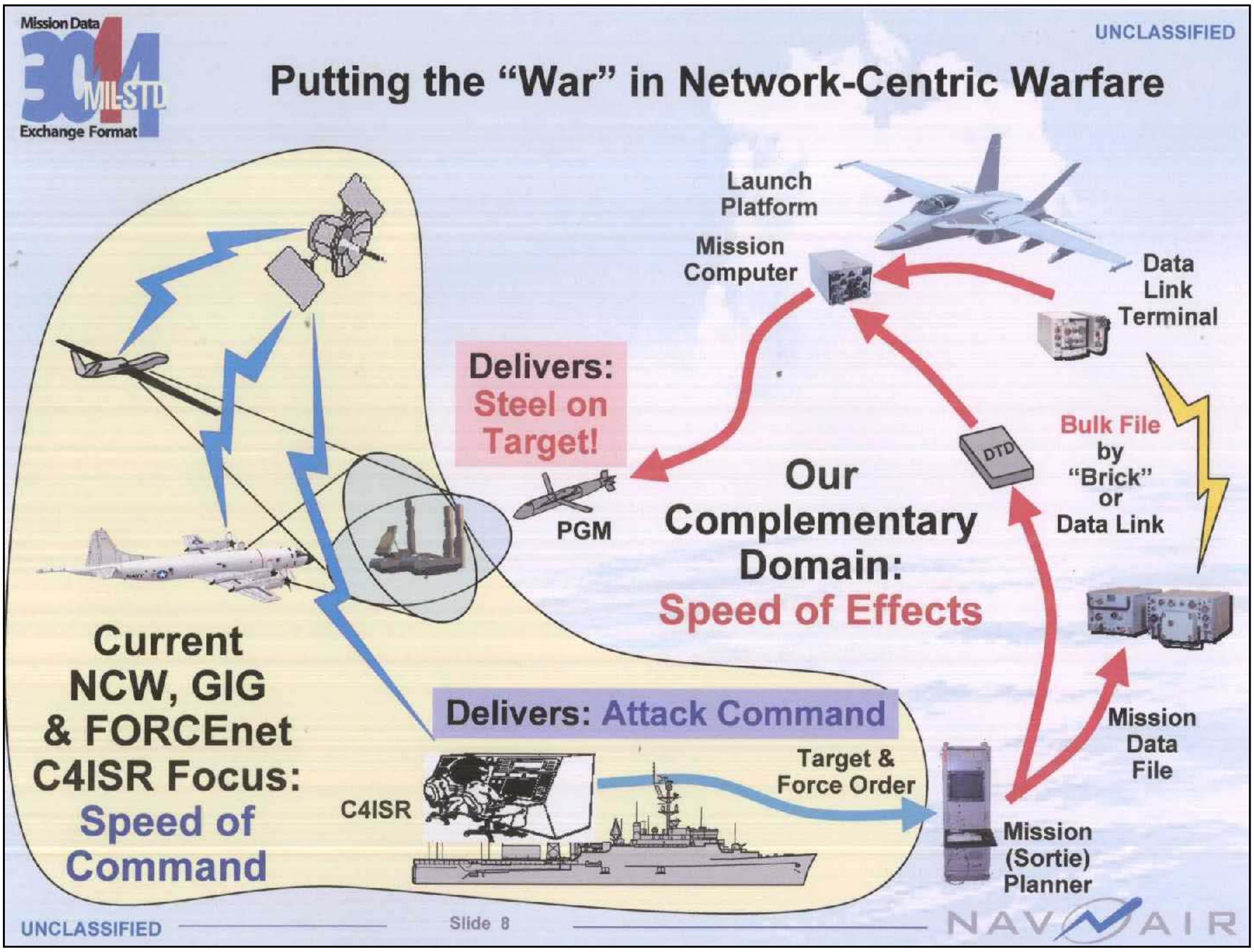


Figure 14a. MIL-STD-3014 – from [14]

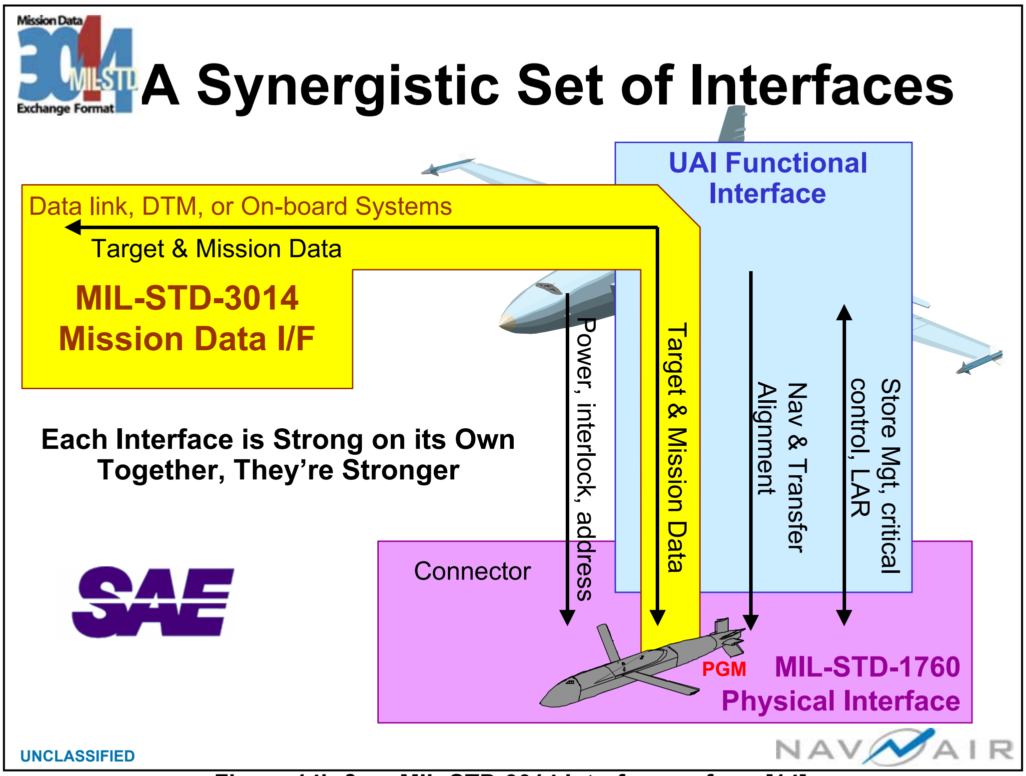
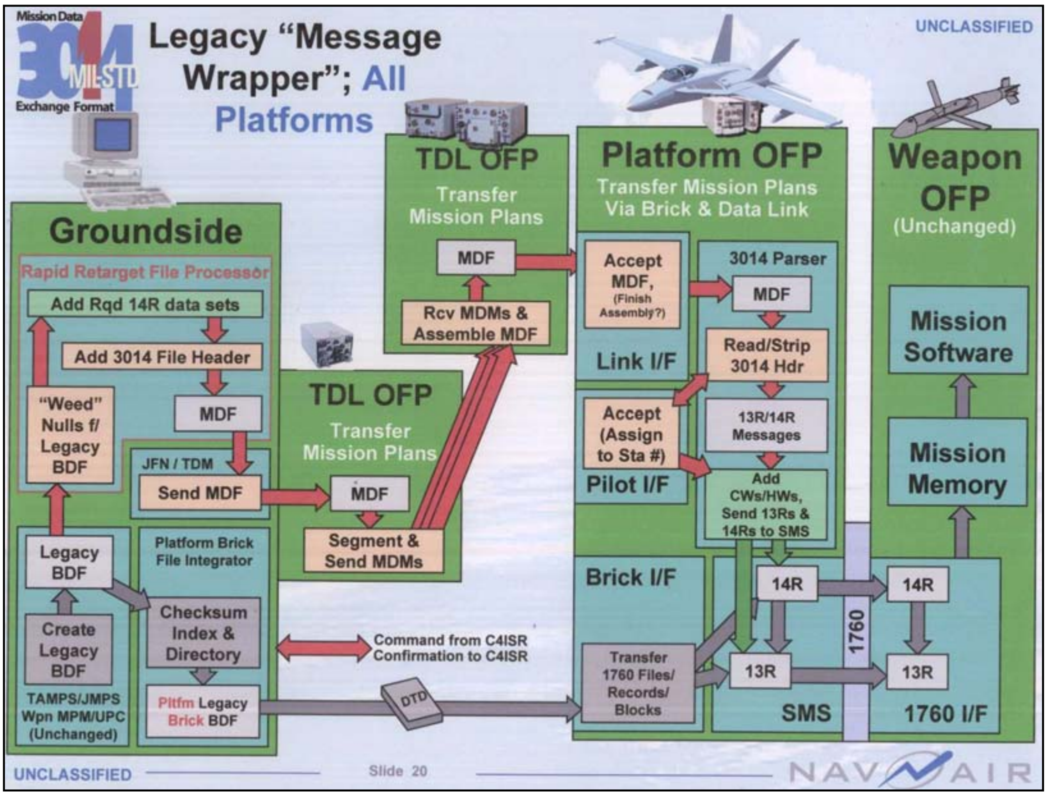


Figure 14b & c. MIL-STD-3014 Interfaces – from [14]



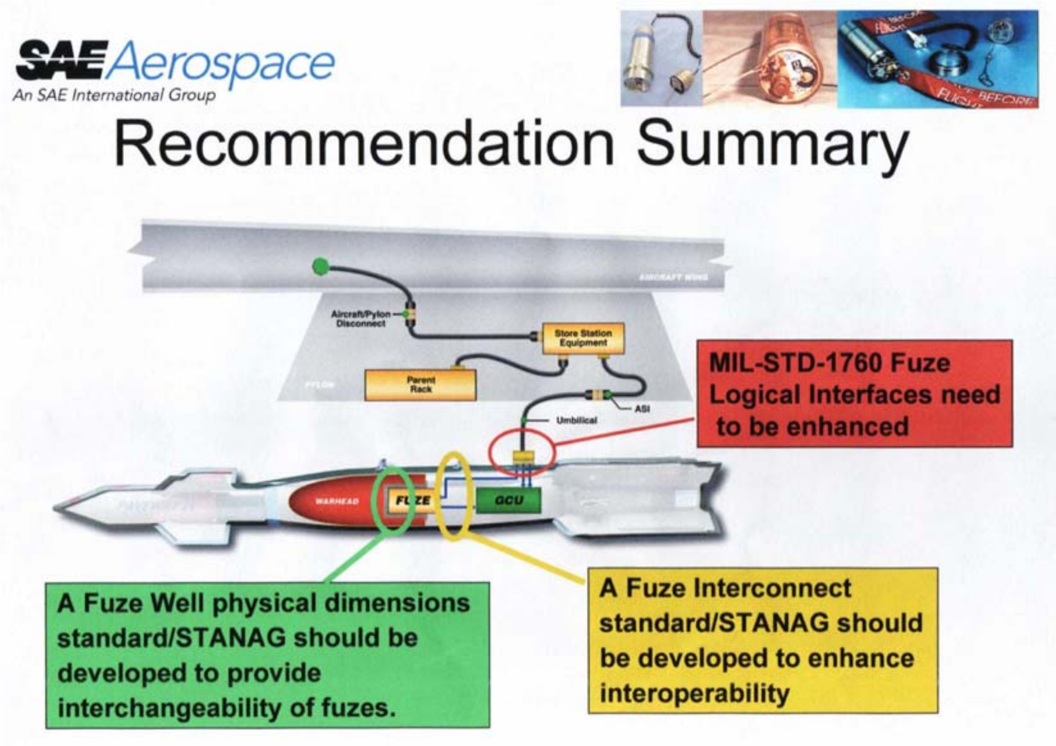


Figure 15. Fuze Interoperability from [15]

Comments are invited on the strategy being taken and the current versions of the information presented in the paper. The most obvious problem with the model being implemented by DCSLCM Manual (2002) is the response time. If one equates the response times for a major acquisition noted at Enclosure 3 to the US acquisition system you will see striking similarity in timescales required to field capabilities to the previous ADF figures from Layton (2000).

11. CONCLUSIONS

The shortest answer is doing. *Lord Herbert, 1640*

The ASCC WP 20 on Air Armament is spearheading initiatives to improve member nation interoperability and understanding for the allies to conduct joint & coalition operations. ASCC needs to complete the recent initiatives on standardising the understanding of each nations technical and operational frameworks for systems engineering, safety, T&E, airworthiness, clearance, S3, air armament design requirements to reduce national duplication.

In summary the three levels of standardisation sought by the ASCC member nations for interoperability can be thought of as:

- **Compatibility** - no unacceptable interactions
- **Interchangeability** - used in place of
- **Commonality** – exactly the same doctrine, procedures, or equipment

The Joint Warrior Interoperability Demonstrations by the ASCC & TTCP nations are contributing immensely to this by improving the Command and Control and secure communication needed to achieve higher organisational interoperability and not just technical interoperability. These Joint exercises need to be continued to explore the NCW concepts being developed before too much money is expended and the operators have even seen conceptually show such a family of systems will work.

System engineering must be used throughout a systems life-cycle to ensure that agreed cost, performance and schedules can be met with some measure of quantifiable confidence. Risk management is an essential part of determining the maturity of the systems being development to determine if a significant change has occurred which will enable the tailoring of the amount of redesign, testing (V&V), publication changes is required. The essential basic steps in the systems engineering process are:

- Define the System Objectives – the OCD and ORD is pivotal, in small projects focus on what is different from an similar existing mature system; establish a framework for systems engineering, risk management and project management that enables all parties to adapt the expected Products with schedule on a case by case basis:
- Establish Performance Requirements that are phased and cannot be misinterpreted by the user and engineers;
- Establish the Functionality – ensure that all subsystem managers have agreed functions and interfaces agreed;
- Evolve Design and Operations Concepts – limit scope to ensure that existing (mature) System Elements / Configuration Items are used to maximum advantage over the life cycle expected;
- Select a Baseline – maturity of the system elements and the organisation managing them is vital and planning for P3I or spiral development;
- Verify the Baseline Meets Requirements – recognising past similar testing & V&V; and
- Iterate the Process Through Lower Level Trades

Having experienced personnel and a company knowledgeable of systems engineering similar projects is vital to reducing the formality of some of the steps and the trade-off studies. To undertake small sized projects, organisations need to establish a system engineering management system that can tailor the process and expected product deliverables depending on the safety criticality, and agreed measures for "significant changes" to keep it as small as practicable with cognisance of the organisations maturity and expected changes in key people. With simple systems or ones with extensive and rigorous systems engineered products and system elements, the key milestones for progressing a new small sized project can be readily tailored while still meeting risk and performance measures. The bottomline is that all key system elements with significant changes need to be properly systems engineered so that drawings and publications are available to affected personnel so they can safely and efficiently operate the system. The dispersed nature of Australian management of capabilities, engineering, T&E infrastructure and operators for aircraft stores capabilities warrants far better command and control to communicate an agreed end state.

A logical milestone methodology based on systems engineering principles has been introduced within the technical and operational airworthiness and quality management frameworks and is in the formative stages of use with several organisations within all ADF services. The recent changes at ARDU to air armament System Engineering and Capability Management need to be addressed for all acquisition projects to improve how we introduce new aerospace combat capabilities.

The approval of OCDs iaw AIAA (1992) and subordinate ORDs must be generated using sound systems engineering principles. Use of ANSI/EIA STD 632 should be used as the ADF Systems Engineering framework, with AAP 7001.054 and AAP 7001.067 being used for aerospace best practice for air armament.

The Aircraft Stores Clearance Risk Assessment Tracking & Models will be further developed and used to better apply risk management principles to establish cost, schedule and performance for aircraft stores compatibility tasks.

Finally the aircraft stores compatibility training provided to all personnel in defence and industry needs to be streamlined and improved to ensure the right aircraft stores capabilities are provided when needed by the Users. This involves practitioners understanding and having experience with:

- A Safety Case for Explosive Ordnance addresses the Manufacture to Disposal Life Cycle
- Certifying aircraft stores configurations against an Operational Requirement involves the operational, engineering and logistics elements issuing the products and the procedures
- Clearance of aircraft stores configurations addresses the key disciplines of
  - Fit & Function;
  - Structural & Environmental;
  - Aeroelasticity;
  - Captive Compatibility, Flying Qualities & Performance;
  - Employment & Jettison; and
  - Ballistics and OFP Validation & Verification, Safe Escape & Safety Templates.
- The use of "Significant Change" tolerances and Modelling & Simulation to add T&E and minimise needless rework by the managers of the aircraft and stores and to maximise the flexibility for inservice operational, engineering and logistics managers
- The use of Risk Management to identify problems early and make responsible (and traceable) decisions.

EPILOGUE

Organization doesn't really accomplish anything.
Plans don't accomplish anything, either.
Theories of management don't much matter.
Endeavours succeed or fail because of the people involved.
Only by attracting the best people will you accomplish great deeds.
Admiral Hyman G Rickover, USN (Retd) "Father of the US Nuclear Submarine" [as cited by Powell]

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ANNEXES:

A. Definitions & Acronyms

B. Currently Approved ADF Air Armament Acquisitions

C. Australia's Next Generation of Capabilities for Tailored Effects

D. International Standardisation Programs

ENCLOSURES:

1. Aircraft Stores Certification FFBD
2. ADF Aircraft Stores Compatibility Systems Engineering Framework
3. Defence Capability System Life Cycle Model
4. Summary of Failure Criticality and Design Assurance Levels
5. Capability Management & T&E "V" Diagram
6. Aircraft Stores Clearance Risk Assessment Model Questionnaire
7. Network Centric Warfare: An Overview of Emerging Theory – Garstkas NCW Paper
8. Aircraft Stores Compatibility Risk Assessment and Tracking V 1.0

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DISCUSSION EDITING

Paper No. 1 Interoperability & aircraft stores certification – an Australian perspective on where to from here

Authors: Malcolm G. Tutty

Speaker: s.a.

Discussor: Prof. N.Alemdaroglu

Question: In all these processes of standardization of weapon system integration , where would you place the role of modelling and simulation?

Speaker's Reply: As shown in the enclosures to my Paper relating to the Systems Engineering and ASC Risk Assessment & Tracking frameworks used by Australia M&S is critical throughout the life cycle from the initial scoping of the T&E and V&V programs at program inception (such as in Requirements Analyses phase), through model refinement and updating during the program which can then be used in other programs with greater confidence. I note that M&S needs to be better integrated in the MIL-HDBK-1763 such that M&S is treated similarly to the Appendice Ground & Flight Tests (see also the Risk Assessment excel spreadsheet for details of this)..

Discussor: Mr. A. Cunningham

Question: Did your example of the F-16 problem concern the effects of lantirn pods?

I recognize the miss hap but do not remember if lantirns were involved.

Speaker's Reply: The "F-16 Problem" shown in the Horror Movie II excerpt shown is the jettison testing of the new "Sargent Fletcher" Fuel Tank in the late 1980s prior to LANTIRN being integrated on the aircraft. The 3246 Test Wing / TY Office for Aircraft Compatibility (now the 46 Test Wing USAF Seek Eagle Office) predicted that such a hit at the specified flight conditions was probable and that the flight conditions be amended accordingly. (It was a big day for the F-16 compatibility engineers to see this occur as we'd predicted.) The F-16 SPO sponsoring the certification effort had insisted that "in absence of any real evidence that a hit was guaranteed" the test should proceed unchanged! From the 3246 Test Wing / TY's perspective the test validated the M&S and engineering assessment. It was very embarrassing and expensive for the SPO though.

Discussor: Osman Basoglu

Question: How do you determine the limitations (Dash1-Ch5) for max "g" (symmetric-asymmetric) and dive angles.?
Where is the place of CFD in these tables.?

How do you determine the critical cases for numerical simulations?

(Since you can not simulate all flight & drop envelope)

Speaker's Reply: Currently the accepted best practice with least risk usually involves the use of US MIL-HDBK-8591H to establish the design requirements for both the aircraft and for the stores. CFD can, and is actively used, in most countries to refine the load factors and hence reduce the assumed tolerances in the design margins so that ALL "flight and drop" operating envelopes can in fact be fully covered in the analyses. This is very important. Under no circumstances would we fly stores in which we couldn't confidently validate the required flight envelope. This takes a lot of experience to avoid too much mass being incorporated into the design which is unrepresentative of the actual flight envelope. Particular care is taken to address any NzW clipping regions to save carriage while maintaining the fatigue life for aircraft and stores and ensuring the stores doesn't break-up under ejection of jettison loads (as shown in the Horror Movie II). The latter criteria is very important with the continued increase in the captive carriage hours of weapons for extended periods due to air tom air refuelling available these days for HE weapons in particular