Topic: Network-Centric Applications

Aerospace Surveillance and Battlespace Management in 2023:

The Impact of Social and Technological Change

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Abstract

Improved aerospace surveillance and battlespace management (ASBM) is fundamental to the defence of Australia and its interests.

DSTO has been asked to assist in the development a capability roadmap for ASBM, which can chart the course from the current systems to the capability required in 20 years time i.e. 2023. In order to do this we need to understand what the possibilities are for ASBM in 2023. We need to identify the fundamental systems attributes required of ASBM in 2023 and the impact of technological and social change on those attributes.

This paper outlines some of the broad technology areas that represent future drivers for ASBM, gives some example technologies and attempts to anticipate in which direction they will “push” the ASBM capability area. The impact that social change, such as personnel shortages, ageing workforce and changing educational requirements, will have on the requirements for ASBM in 2023 is also addressed. The risks and challenges in achieving this goal are then discussed and a comparison made between the “ideal” ASBM, ASBM in 2023 and the current situation.

1. Introduction

Improved aerospace surveillance and battlespace management (ASBM) is fundamental to the defence of Australia and its interests. The Defence White Paper, *Defence 2000* [1], predicts significant increases in regional air-combat capability in the next 10 years and in that time, Australia will acquire new aircraft, weapons, sensors and supporting information technology and telecommunications. ASBM must also deal effectively with diverse levels of threat, under varying political and diplomatic constraints. All these factors will contribute to the effective management of the air battlespace becoming more complex and demanding.

ASBM has been recognised as one of the four capability areas for the Royal Australian Air Force [2], the others being offensive combat, flexible combat support and rapid mobility. The Defence Science and Technology Organisation (DSTO) has been asked to help develop a capability roadmap for ASBM, which can assist in charting the course from the current systems to the capability required in 2023.

In order to do this we need to understand what the possibilities are for ASBM in 2023. We need to identify the fundamental systems attributes required of ASBM in 2023 and the impact that future technological and social change will have on these attributes. Having done this we can then look at the constraints that will be placed on the evolution of ASBM by existing legacy systems and operational, technological, financial and sociological factors.

This paper outlines some of the broad areas that represent future drivers for ASBM, gives some example technologies and attempts to anticipate in which direction they will "push" the ASBM capability area. The impact of social change on the requirements for ASBM in 2023 will also be addressed including the impact of personnel shortages, ageing workforce and changing educational requirements. The risks and challenges facing the development of ASBM are discussed and a comparison made between the "ideal" ASBM, ASBM in 2023 and the current situation.

2. What is ASBM?

The ASBM capability to be generated in the next 20 years, i.e. by 2023, is not a single platform but a concept to be developed, an environment to be supported and an ongoing system of systems to be acquired, integrated and deployed. Aerospace Surveillance and Battlespace Management (ASBM) is the term that has been adopted in Australia to cover the work done in compiling the operational air picture and controlling the assets in the air space in order to achieve the effects required by the operational commander.

The term battlespace describes the combination of the physical and cognitive domains that must be managed by a military commander. In the physical domain, it has traditionally included all aspects of the air, subsurface, sea surface and land domains that encompass the area of influence and interest. With the development of sensor and communications technologies, the region of interest has been extended to include the electromagnetic domain. The Defence White Paper [1] notes that the effective use of information is at the heart of Australia's defence capability, and in particular is central to any system to support effective ASBM.

Due to its size, Australia has a very large area of interest. Consequently, Australia uses many disparate sensors from over-the-horizon radar through to civilian air traffic control radar to form an integrated air picture.

Aerospace battle management provides command and control for both defensive and offensive aerospace activities in an operational area. This will include but is not restricted to the coordination of defensive counter air, offensive counter air and strike missions as well as other war fighting activities.

Aerospace management provides for the safe, efficient and flexible use of airspace for legitimate military and civilian users. The civilian Airservices Australia coordinates airspace management for non-military aircraft in national airspace during peacetime. The efficient conduct of military operations, during both peacetime and conflict, requires interoperability and coordination between the airspace management systems of both the ADF and Airservices Australia.

3. Relationship to Network Centric Warfare

The ADF has outlined its vision for the future in *Force 2020* [3]. This future force will be seamless, network-enabled and support effects-based operations. The ADF Future Warfighting Concept [4] describes the Australian view of Network Centric Warfare (NCW) as follows:

> *"Network-centric warfare* (NCW) is a key enabler that will allow us to conduct Multidimensional Manoeuvres, and achieve the seamless force envisaged in *Force 202*0. Network-centricity will help us to link national, ADF and coalition sensors, engagement systems and decision-makers into an effective and responsive whole. At its core, NCW seeks to provide the future force with the ability to generate tempo, precision and combat power through shared situational awareness, clear procedures, and the information connectivity needed to synchronise our actions to meet the commander's intent. NCW will require an approach that integrates our existing processes and systems with new technology and doctrine in the most effective and efficient way. NCW might offer us a whole range of warfighting advantages, including the ability to focus limited resources using our superior knowledge, increased protection for our forces through information, and an ability to share information quickly and securely across current boundaries. It also contains potential vulnerabilities, including those arising from reliance on high- technology communications and increased data flows."

In order to achieve the vision of *Force 2020* the ADF is adopting concept-led long range planning. This involves identifying the major drivers and future missions for the ADF and then developing operational concepts and capabilities, which will be rigorously tested through experimentation.

The key aspirational concepts for NCW are

- A geographically dispersed force,
- A knowledgeable force,
- An effectively linked force, and

- A force designed for networking.

These concepts are fundamental to ASBM, which is a major component of any network-enabled force of the future.

4. The Ideal ASBM

In order to undertake capability planning for future systems it is necessary to be able to define the design goals and attributes of the future systems. While these goals and attributes will be constrained by the development of technology and current procurement projects and policies, it is useful in preparing a roadmap for the future to look at what an ideal ASBM might be like. The attributes of the ideal system and an understanding of the technological, organisational and social drivers, which will occur, can then be brought together to help identify achievable goals for the evolution of ASBM. This section describes the attributes of an ideal ASBM system. They are broken down into three areas: operational, systems/technology and organisational/management.

4.1. Operational

- Seamless Joint operations within ADF are the norm – there is shared doctrine, operational culture, training and knowledge.
- Seamless coalitions operations are possible with known allies – cultural and linguistic challenges are minimised, systems are interoperable and dissemination of information amongst coalition partners is seamless and automated.
- A wide variety of sensors are available to provide the Integrated Air Picture and sensor and control systems are deployable at short notice to provide services at forward operating bases.
- Identification Friend or Foe (IFF) systems are sufficiently advanced so own forces and coalition forces are unambiguously identified.
- While all source information is available, the decision maker normally only receives the information that is relevant - tailored products which have minimal cognitive dissonance. This information is timely and fusion of all information sources including intelligence reports is automated.
- Training and mock scenarios are integrated into the normal working patterns, that is, a state of high readiness is always maintained. This is achieved through a combination of real and synthetic data stimulation. Planning and scenario analyses make extensive use of simulation and modelling to evaluate their quality. Synthetic warfighting is used extensively
- The force is designed for NCW techniques such as swarming[1] and organisation and doctrine is in place to support them. Characteristics include: smaller autonomous forces, flatter command structure, shared situation awareness, ubiquitous communications, third party targeting and cooperative engagement.

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[1] Swarming [6] is defined as " systematic pulsing of force and/or fire by dispersed, internetted units, so as to strike the adversary from all directions simultaneously"

- Appropriate force mixes are available and able to be assembled as rapidly as required e.g. short/long range, attack /surveillance, manned/unmanned

4.2. System / Technology

- Appropriate architectures are in place providing a robust, resilient and agile ASBM. Modularity and interoperability drive design decisions. New components (platforms, weapons, sensors) can be readily integrated into the ASBM system (plug-and-play) and the system is able to reshape dynamically depending on scenario and command authority requirements. There is no single point of failure.
- Computer advances enable widespread automation of routine tasks. Automated decision aids and knowledge manipulation are widely used however, it is recognised that the level of automation must not reduce the existing levels of human situation awareness.
- All communications mechanisms have adequate bandwidth and sufficient reach to meet all foreseeable deployments. Sensor-to-shooter and commander-to-shooter lags are almost non-existent. All communications and computers are secure and protected from IO attack
- Sensors are tuneable to targets and of sufficient resolution to classify targets. There is increased use of passive sensors and intelligence products are fused with sensor inputs.
- Sensor and weapon systems are sufficiently small and efficient to have negligible impact on the platform hosting them and stealth is commonplace (miniature platforms are available).
- Perfect exploitation of the EM spectrum – friendly communication is not jammed or intercepted but the adversary is denied use of the EM spectrum for communications or sensors. The adversary's communications are intercepted.
- Unmanned platforms are prevalent and have high levels of autonomy. Ground-station-based control is largely unnecessary and redundant. Unmanned platforms have defence/attack and surveillance roles and co-operatively interact with manned platforms
- Space-based assets are widely used for surveillance and high bandwidth communications relay. Space-based weapons are only available through allies.
- Systems use self-diagnosis and can self-repair. Autonomous logistics systems are common and reduce the maintenance down time significantly. Critical components are indigenously sourced (or at least modifiable within Australia). Software is a significant and increasing proportion of defence procurement.

4.3. Organisational / Management

- Management structure is chosen to minimise information overload and to maximise decisiveness. Judicious combinations of hierarchy and flat structures are used. Task forces or "tiger teams" are prevalent. Surveillance is likely to be traditionally structured whilst Battle Management is more fluid depending on the threat scenario.

- People may work off-site or in distributed teams and access to external experts is facilitated through communication and Internet mechanisms.
- Automation is prevalent but people make final interpretations and decisions. As demographics suggested, shortages of skilled staff are a significant issue and automation helps negate personnel shortages.
- Pay and reward structures match those of comparable commercial enterprises. Recognition of ASBM as "knowledge work" means rewards and management are focussed on skill acquisition and staff retention. Knowledge transfer is enhanced through mentoring and job rotation (within strictly defined constraints). Outsourcing is not applied to "core" competencies
- Whole-of-nation responses and long-term collaborative partnerships are in place with other government departments, agencies and non-military organisations. For example, a National Surveillance Centre is responsible for surveillance of Australia and its Economic Exclusion Zone (EEZ).

5. Drivers and Issues

Before we can achieve this ideal ASBM system, we must understand the issues and drivers that will change the way future systems will develop and evolve.

5.1. Strategic & Operational Drivers

Within Australia, and as evidenced by the 2000 Defence White Paper[1] and the more recent document, *Australia's National Security – A Defence Update 2003*[5], there is a trend towards transitioning the ADF to a more expeditionary force. It follows that high level functions of deployment and sustainment will receive greater attention from capability developers in the future. ASBM is no exception - the AEW&C aircraft and Mobile Regional Operations Centre (MROC) are both set to provide the RAAF with an in-theatre ASBM capability by 2007.

More often than not, Australian forces will be deployed as part of a larger coalition force. Interoperability with these coalition partners, typically our traditional allies (U.S.A. and U.K), has become a high priority for the government. One example of work directed at creating seamless coalitions is the Coalition Integrated Air Picture (CIAP), a study coordinated by The Technical Cooperation Program (TTCP)[7]. Although only a small part of the total problem, the CIAP is seen as a test-bed for continued research into improved integration of coalition forces.

The potential for future coalitions to be formed with regional defence forces is also being considered by the department. A major study into the integration of the Joint Strike Fighter (JSF) into regional coalitions has recently been initiated with funding from the JSF program office. A regional coalition may see Australia taking a lead role in providing in-theatre ASBM support. However, for the immediate future, the need to work effectively as part of a regional coalition will not outweigh the need to form effective coalitions with our traditional allies.

The breadth of operations that are likely to be conducted by the ADF, while they are deployed, is growing. In the past decade, we have seen limited conventional warfare, peacekeeping, peace enforcement, sanction enforcement and a number of hybrids.

Operational tempo has also increased dramatically over this same period and concurrent operations are gradually becoming the norm rather than the exception. Despite these facts, the least likely scenario, defending an attack against the Australian mainland, remains as the highest priority for Defence.

Conflict against organisations other than nation states is a reality now and will probably still be an issue in twenty years time. This type of conflict is characterised by the difficulties associated with trying to understand the nature of the adversary. In general, the adversary will not have any significant fixed infrastructure. This means that targets are generally time-critical and thus, the importance of thorough surveillance, timely reconnaissance and minimising the sensor-to-shooter lag becomes paramount.

An Effects-Based approach to operations is one of the key tenets of the ADF's 'Force 2020' [3]. Air power, through surveillance, reconnaissance and precision strike will remain as a key tool for achieving effects-based outcomes in various types of operations into the foreseeable future. In turn, ASBM will enable the use of air power in an effects-based role.

A Whole-of-Government approach to Defence business (perhaps driven by the perception of departmental stovepipes), may lead to greater sharing of information and resources between Defence and other government departments and agencies. This is of particular relevance to maritime and Wide Area Surveillance (WAS) where greater cooperation with the Australian Quarantine Inspection Service (AQIS), Customs, Coastwatch (or perhaps a future Coastguard organisation) may be sought.

5.2. Technology

Technologies will continue to develop and will offer the potential to improve the way in which ASBM is conducted. That is, technology will act as an enabler for achieving the vision laid out in Section 4.

5.2.1. Sensors

Sensors represent the interface between the physical world and the information space that can be exploited by decision makers. The range of different sensors that are able to contribute to the aerospace surveillance picture is growing and will continue to grow into the future. These sensors will include active sensors such as monostatic microwave radars, bistatic microwave radar networks and high frequency radars (such as Over The Horizon Radar systems and Surface Wave Radar systems) [8,9]. Increasingly, passive sensors will make a significant contribution to the compilation of a Recognised Air Picture (RAP). These passive sensors may include space-based infrared sensors, networks of acoustic sensors or networks of ESM (Electronic Support Measures) sensors that are able to detect and track radiating platforms.

Of course, no single sensor system will provide a 'silver bullet' for aerospace surveillance particularly if an adversary is using stealthy platforms. Instead, the key to realising the full potential of aerospace sensors lies in developing processes for the fusion of data from these numerous sources. Without proper data fusion systems there is potential for the ASBM commander of the future to become overwhelmed by the volume of available sensor data. However, fusing data from disparate sensors, in a timely manner that allows the decision maker to quickly assimilate the overall picture and make a well-informed decision is a non-trivial problem.

5.2.2. Platforms

Platforms provide ASBM with information gathering reach. They also represent the smallest unit of force that must be managed by ASBM.

Proliferation of Unmanned Aerial Vehicles (UAVs) will result in a wide variety of platforms that are able to conduct a multitude of tasks [10, 11]. Small, or tactical, UAVs may be used for Electronic Warfare (EW) tasks (such as Radio Direction Finding – RDF or receivers for bistatic radar systems) while large solar-electric UAVs, that are able to remain on-station for months at a time, conduct surveillance or communications relay tasks [9]. The armed equivalent of the UAV, the Unmanned Combat Aerial Vehicle (UCAV), will likely conduct tasks such as Suppression of Enemy Air Defence (SEAD), land strike, maritime strike and Combat Air Patrol (CAP) perhaps as a component within manned / unmanned aircraft teams. The need for robust integration of UAVs and UCAVs into existing Air Traffic Control (ATC) processes will be forced upon ASBM planners in the not-to-distant future.

Increased autonomy of UAVs will allow for the automation of some routine tasks such as wide area surveillance. Ground segments will no longer be required to control or monitor low-level vehicle functions and hence the control of UAVs will more closely approximate the control of manned platforms [12]. Ideally, UAVs could be given a broad set of objectives from which they can derive a flight plan, execute that plan and return to a safe base. Human intervention in the mission would only be required in exceptional circumstances.

The planned introduction of the F-35 in 2012 will signify the ADF's first experience with the use of stealthy platforms (other than perhaps low observable tactical UAVs). The impact of 'friendly' stealth on ASBM is difficult to quantify but certainly new tactics will be developed to maximise the advantage of stealth. The constraints associated with stealth, such as reduced weapons loads (due to internal carriage of weapons), will also influence the development of new tactics. In turn, these tactics may affect the number of platforms used for specific missions and the way in which those platforms are managed.

5.2.3. Computing & Communications

One of the easiest technology forecasts is that available computing power will increase. The various growth laws (Moore [13], Gilder [14]) indicate that computers will be 2^{13} quicker, storage will be 2^{13} larger whilst being significantly smaller (physically) and bandwidth will be 2^{20} greater than today. Some of these estimates may even turn out to be conservative as new approaches and technologies (nano and atomic level computers and storage, quantum computing, etc) suggest major paradigm shifts leading to even greater capabilities. Even assuming these laws slow down (Moore's law, which describes the current growth in memory and computing power, may stall as physical limits of component density are reached, but this isn't likely to occur within fifteen years), we can safely assume a 2^{10} increase in these characteristics over the next twenty years. Perhaps more than any other technological area, computing is an external actor on ASBM; the developments described here will take place regardless of whether or not the military world seeks to exploit them.

Application level developments in pattern recognition, decision aid technologies, military simulation and automation tools will assist in the processing of raw data into useful information that can be exploited by decision makers. They may also provide the opportunity to hasten transitions through individual or organisational observe-orient-decide-act (OODA) loops, improving the overall response times of ASBM as a system-of-systems.

The combination of ubiquitous computing with wireless data networks will improve the reach of information sources such as the World Wide Web. In addition, semantic web technology may pave the way for powerful data fusion tools (perhaps also making use of intelligent agent technologies) that are able to mine data from numerous disparate sources, check the data for completeness, repetition and relevance and produce tailored reports that meet individual needs [15].

Proliferation of high-bandwidth satellite data links that will be available to deployed forces will allow for the dissemination of 'rich' information products, such as a Recognised Air Picture, to a wider group of recipients. Additionally, a wider group will be able to provide raw information for the generation of these products.

The rollout of tactical data links such as Link-16 will also have a significant impact on the ASBM capability area. Tactical data links will lay some of the technical groundwork for implementing NCW related concepts such as cooperative detection, cooperative engagement and self-synchronisation. Long-endurance UAV platforms, satellites or some other long-endurance platforms, carrying communications relay payloads, will be critical to maintaining an integrated network for widely dispersed forces, as would often be the case for operations in the Australian theatre.

5.3. Organisational

ASBM (now and in the future) involves knowledge workers [16] and knowledge acquisition, analysis and exploitation. The knowledge worker brings a new dimension to management and the organisational structures needed to support it. Most management theory and practice has developed within a manufacturing [17], bureaucratic or military context. Drucker [18] argues that we are entering a knowledge society in which knowledge is the basic economic resource (supplanting capital and natural resources) and where knowledge workers will play a pivotal role.

Knowledge workers bring different expectations to the workplace and are expected to be less amenable to C2 strategies and less loyal to a particular employer [19]. It is expected that knowledge work will be less hierarchically structured. Because of this, an effective future ASBM will need to develop organizational structures, cultures [19], competencies [20] and capabilities [21] to support knowledge work and knowledge workers. Senge [22] proposed the Learning Organization as a model to meet these requirements. Nonaka and Takeuchi [23] claim that most current management theory and practice does not support knowledge creation. Their "middle-up-down" proposal addressed this problem from a Japanese perspective.

Corporate organizational structures tend to change slowly and are driven by pragmatism. So different models need to be both researched and tested within a military context to confirm their applicability to ASBM.

5.4. Societal Change

In common with much of the developed world Australia has a falling fertility rate and an increasing life span for its older citizens. Whilst Australia's population is expected to increase due to continuing immigration [25] the composition is changing dramatically. The proportion of the population younger than 64 is declining (from 1991 to 2021: Ages 0-14 from 21% to 17% and 15-64 from 67% to 65%) whilst those over 65 is increasing (from 1991 to 2021: Ages 65 and above: from 12% to 16%). In addition to the declining fertility rate, family formation is being deferred (from 1977 to 1997: female age at first child increased from 25 years to 30 years) and this is contributing to a decrease in children born to Australian parents (which has been trending down since 1991). So, whilst the population is increasing (through immigration effects) the proportion available for Defence is steadily declining and will probably continue to decline (if broader world trends are reflected in Australia).

Australia's youth are well educated (particularly so in relation to our neighbouring countries) and widely exposed to computers and sophisticated communication technologies. Within the private secondary school sector, retention rates have been above 80% for boys and girls (with girls having about 8% higher rates). At the tertiary level, the participation rate increased from 1993 to 1998 by 17% with larger increases for girls (55% of higher education students are women) [25]. One trend that may impact education attainment within Australia is the decreasing proportion of GDP being spent on tertiary education.

These population and educational trends will impact Defence's choice (and availability) of personnel for ASBM. The availability of recruits may not be a major issue if the current decline in permanent Defence personnel continues (from 1990 to 2000: Navy declined 15%, Army 25% and Air Force 30%). Recent increased Australian involvement in military activities may reverse these declines.

The current requirement for Australian Citizenship may drastically reduce the available pool of personnel. In June 2000, 23.6% of the Australian population was born overseas [26]. Even for Australian citizens, ethnicity and language differences (offspring of immigrants from non-English speaking countries) will create special challenges for Defence and thus for ASBM in Australia. On current trends, population growth, within Australia, of immigrants from non-allied countries is increasing whilst those from allied countries are decreasing.

6. Risks, Challenges and Possible Solutions

The evolution of today's rudimentary ASBM will need to overcome various challenges and risks. These include the impact of rapid technological change, organisational interoperability issues, social change and human limitations such as cognitive overload. These issues and possible solutions are discussed below.

6.1. Rapid Technological Change

While the technological trends and increasing capabilities of computers, communications and sensors will solve many of the technical challenges over the coming twenty years, they will also have major social impacts.

The digitisation of reality will impact how people interact, how and where they work and how they analyse and interpret the world. Rapid technological change will make it difficult for our social structures to keep pace and there are certain to be large experiential gaps between various age groups within society.[2] One potential outcome of this may be that the young will command the old. In times of rapid change, many forms of expertise quickly become obsolete and education and training are more significant than experience[3].

The increasing availability of high bandwidth communications will facilitate people performing routine work off-site and access to external experts will be facilitated through communication and Internet mechanisms. Given that the current generation (who will become future ASBM personnel) are immersed in these connected systems, the ability to impose effective corporate structures may be limited. This mismatch between mainstream culture and military culture will provide a major managerial challenge to the provision of effective ASBM.

6.2. Information Warfare

The need to rely on technical systems and their output for situational awareness and decision-making creates a systemic risk to ASBM in the area of information warfare. The criticality of this infrastructure makes it imperative that the system and all its external interfaces and communication links are secure and tamper-proof. Within a coalition, this will be exceedingly challenging as the level of trust and the sharing of information is strictly constrained. The provision of information at varying levels of security will greatly complicate the design, operation and interoperability of such systems.

6.3. Interoperability

The extended vision of ASBM to include coalitions and whole of government concepts will make interoperability critical and, whilst systems may be interoperable (at least at the data interchange level), the broad interoperability issues associated with doctrine and culture will be an on-going challenge. New models to account for so-called organisational interoperability are being developed to increase the understanding of the issues [24].

6.4. Financial

One of the biggest risks, within the Australian context, is not technological but financial. Many solutions will be available but they may be too costly for Australia. Many high technology systems are certain to be sourced from outside Australia. (A corollary of this is that procurement decisions will be more difficult.) Given Australia's financial constraints it will be critical that Australian acquisitions are interoperable and backwards compatible so that various generations of systems are interoperable.

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[2] We see this today with the slow adaptation of the Law to the Internet

[3] For example in today's context: of what value is a skilled analogue camera repairman when cameras are fully digital and constructed of computing components

6.5. Demographic changes

Future ASBM will be a knowledge-based task demanding high-level skills, experience and decision-making abilities (both corporately and individually). Thus, a major challenge is the provision of sufficient, well-educated personnel to provide ASBM. Whilst the Australian population will continue to grow through immigration [25], the proportion available for recruitment is declining. Even the provision of education may be impacted by this demographic trend; education is but one of many societal needs and the support and assistance of an increasing "aged" population will consume resources that might otherwise be spent on education.

6.6. Cognitive overload

A major risk to the effective use of these increasing capacities is the limitation of human cognitive abilities and particularly the risk of cognitive overload, which impairs human information analysis and decision-making. Cognitive overload has been described as "...the overload that arises from multi-tasking, interruption and information overload" [27,28,29]. This overload[4] is partially inevitable, as it is well known that people can only deal with seven (plus or minus 2) items at once in their working memory [30]. This biological constraint is unlikely to change although there is some evidence that drugs and diet [31] can slightly increase this capacity. Even so, increasing complexity quickly overwhelms minor improvements in human capability. Automation can reduce the cognitive load but only if it is designed to stay within the working memory limits. The advances of the Web (including email) and search tools have contributed to information overload [32].

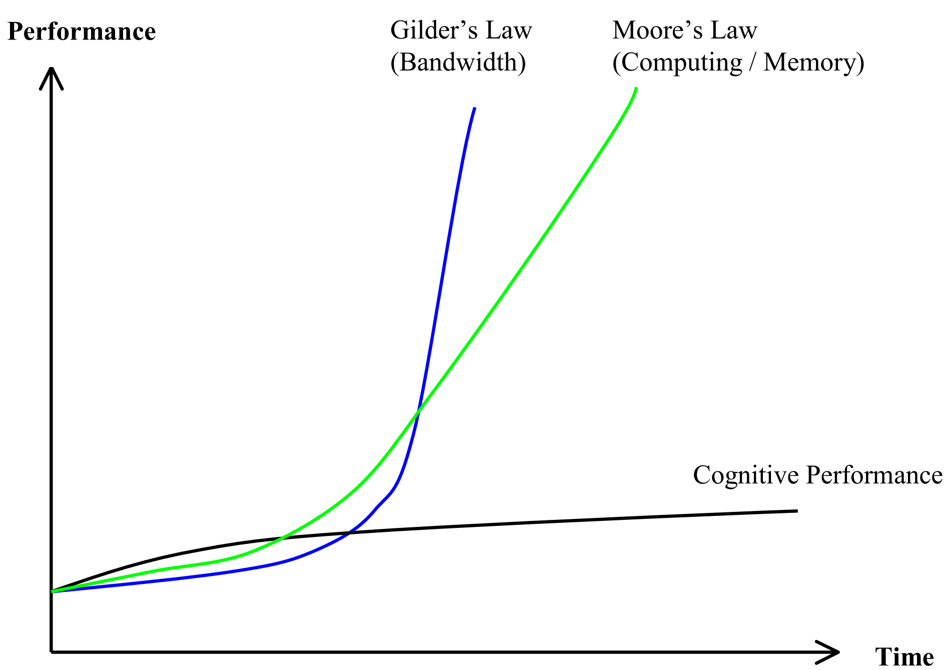

Figure 1 Computer Growth Laws vs. Human Cognitive Capabilities

[4] This overload has impacts beyond work effectiveness and leads to significant stress related syndromes.

Figure 1 shows the relative effects of the computer growth laws referred to in Section 5.2.3 versus human cognitive capabilities.

Within ASBM, cognitive overload will be created by obvious influences like the tempo of activities, the diversity of technologies which will be available for both sensors and battle management (this diversity demands that decisions be made as to deployment and appropriateness of usage); but also complexity will be extended by the nature of Australia's extended vision of ASBM. Whilst Joint warfighting should be well understood and manageable, the provision of ASBM in coalition operations and within a whole of government setting (interacting and cooperating with other non-defence government agencies), for military and operations other than war (OOTW), will significantly increase the complexity of ASBM decision-making.

Unfortunately, the use of technology to solve the cognitive overload problem is a two edged sword, it may actually increase the problem. Whilst it is obvious that decision aids and information abstraction services will assist the decision making process, these aids need to be designed as integrated packages which can be tailored to the individual user. The provision of discrete tools only exacerbates the problem. Decision aids need to be designed so that the user can extract the key decision components to allow for evaluation and override of automated decisions. The representation and presentation of information to ASBM operatives will critically impact cognitive load and future research and experimentation will be required to improve these capabilities. Whilst current trends favour realism (immersive displays, video feeds, etc), future systems will abstract information and selectively present focussed information. Future systems will also monitor and evaluate a user's cognitive and mental state to vary the level of automated support and presentation characteristics to ensure maximum engagement and reduced cognitive load [33]. To mitigate these human frailties it is important to consider human factors [34] when designing any system to reduce cognitive overload and this will require active research within the Australian context.

The development of these aids will partially be derived by increasing use of problem solving techniques like genetic algorithms, neural networks and algorithms based on swarm intelligence [35, 36, 37] and other approaches (yet to be discovered), that is, computers will increasing generate solutions with minimal human intervention. The increases in computing power (and storage capacities) are making feasible techniques that are currently constrained or impossible [36]. The achievement of these advances will require creative use of the enhanced capacities and the development of software-based solutions.

No doubt, many errors and weaknesses will be encountered and overcome as this automation is developed and through this process peoples' faith in these systems will increase[5]. Once this trust is established, the cognitive load will be decreased as the outputs from decision aids can be used without question (or at least be accepted as being better than that generated by people). The creation of these trusted systems will also

[5] For example: automated weather prediction is a trusted science, which is rarely questioned, and the complexity and number of the parameters used, makes it beyond human capability.

require significant cooperative research effort within Australia and between Allied research groups

The other solution is purely managerial, namely identifying what organisational structures should be employed, what capabilities need to be established and what core competencies need to be developed and nurtured to provide effective ASBM. These organizational structures will need to be designed to reduce cognitive overload. Although it is currently being predicted that organizations will be less hierarchical [38,39], Leavitt [40] argues that hierarchies help satisfy human needs for recognition and advancement and have other benefits which will ensure their continued existence. It is expected that a judicious combination of hierarchy and flat structures will be required to support ASBM. Task forces or "tiger teams" will be prevalent and formed to tap into the special skills and knowledge required to achieve a goal. Surveillance is likely to be hierarchically structured whilst Battle Management will be more fluid depending on the threat scenario.

6.7. Training and Retention of Knowledge Workers

Assuming that personnel can be recruited and retained, there is no doubt that ASBM will be based on knowledge and its "knowledge workers" will require continual training. Such high skill levels and long gestation periods are sure to require mentoring as an active mechanism for skill acquisition and sharing. Additional training will be integrated into daily work to provide and promote a high degree of preparedness. It will be built around synthetic warfighting and extensive use of simulation and modelling. The integration of 'virtual' training as one of the high level functions of military systems will become commonplace over the next ten years. The value of conducting training within the normal working environment, with the standard Human Machine Interface (HMI), has been demonstrated with Concept Technology Demonstrator (CTD) systems such as the DSTO Virtual Air Environment (VAE). The expertise developed by these mechanisms will greatly assist in reducing with cognitive overload.

This heavy investment in human capital creates another challenge: the retention of such highly trained personnel. (The cognitive skills required for ASBM will be readily transferable not only to other military services but also into the broader workplace). Evidence suggests that simple mechanisms like pay and conditions will not solve the retention problem [41]. Knowledge workers are expected to be less responsive to authority figures, more responsive to knowledge and skill [19] and hence less committed to any particular workplace or employer. The creation and nurturing of a "learning organization" [22] will assist in developing knowledge workers and retaining their commitment. Japanese approaches to management [23] will need to be explored and possibly integrated into ASBM.

Intrinsic motivators and soft skills, like people management, will be critical to the creation of an environment that retains people's interest and dedication. The Economist presented a survey of the skills needed for effective management in the year 2010. In descending order they were: communication skills 94%, decision-making 89%, professional relationship building 74%, cultural sensitivity 73%, conflict resolution 58%, ability to excel in ambiguity 57%, technical skills 53% [42].

7. Evolution of ASBM Attributes

The preceding sections have discussed the ideal ASBM, the drivers for change and the possible risks and challenges facing the evolution of ASBM. The following "spider" diagrams provide a useful way of visualizing the changes that will occur as the ASBM capability development proceeds towards the ASBM of the future. Each axis is one attribute and the shapes overlayed show a comparison of the current situation in 2003, the ideal ASBM, as described in Section 4, and an estimate of the ASBM possible in 2023.

Figure 2 shows some of the operational attributes. The Australian ability to perform NCW is currently very limited and there are significant interoperability problems in particular with coalitions. To achieve the capability envisaged for 2023 there will need to be significant development of operational concepts and doctrine.

Of the technological attributes shown on Figure 3, some such as stealth and autonomous systems are currently non-existent in Australia. As these technologies mature, they will be integrated into Australian capability. Adoption of others such as sensor and communications technology is already well advanced towards the 2023 capability.

The organisational and management attributes shown in Figure 4 also reflect the gap between the ideal and what may be achieved in 2023, which may be limited by imposed organisational constraints and by human characteristics. Whilst it is recognised that current ASBM is knowledge work, in the future the emphasis will move to the collaborative use of knowledge. It is also recognised that the organisation will never be completely non-hierarchical or completely distributed and while the ideal ASBM may be complete flexible, in 2023 the system will be constrained by the force mixes available.

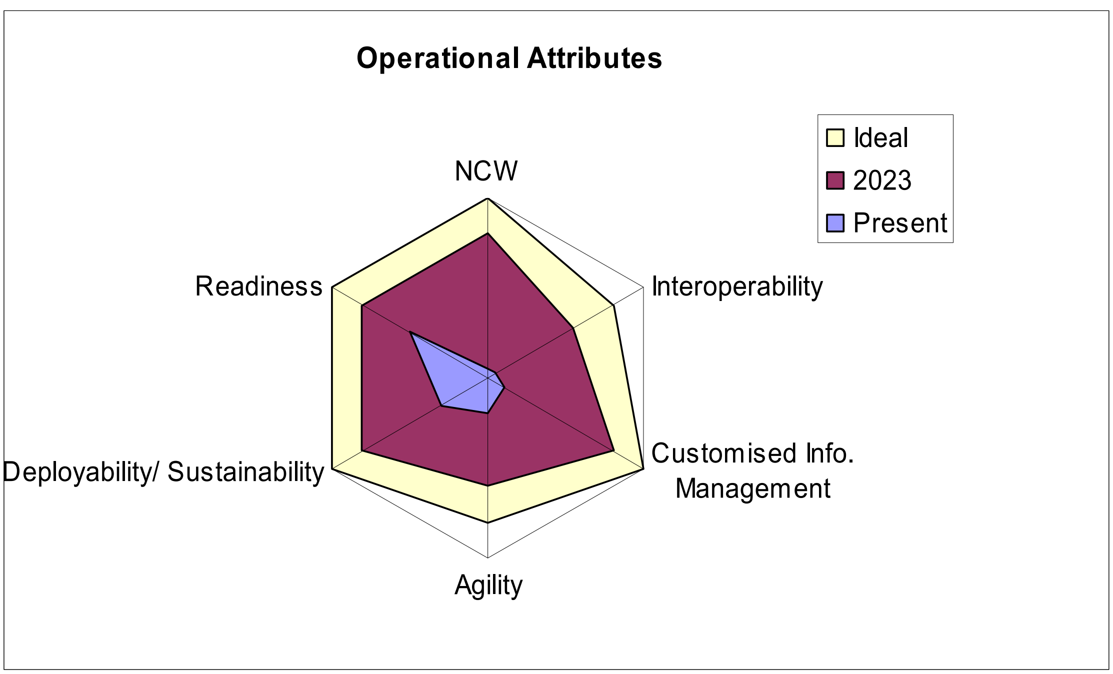

Figure 2. Operational Attributes of ASBM

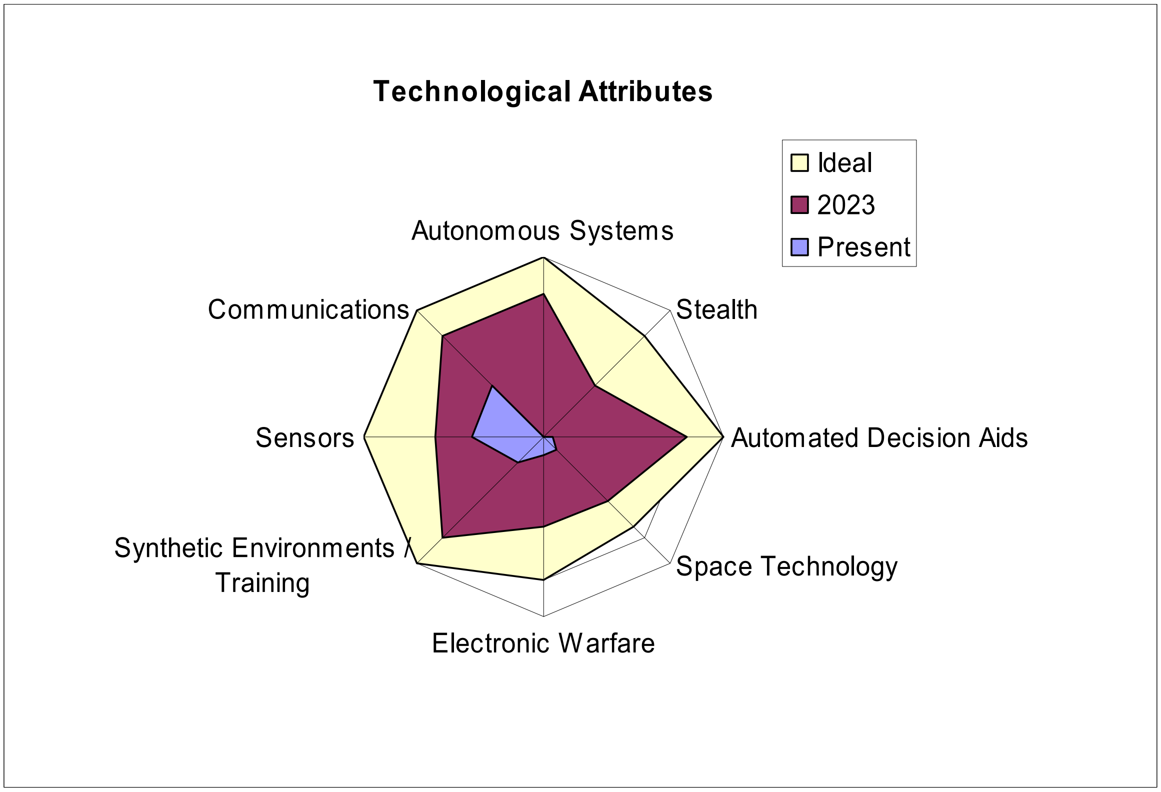

Figure 3. Technological Attributes of ASBM

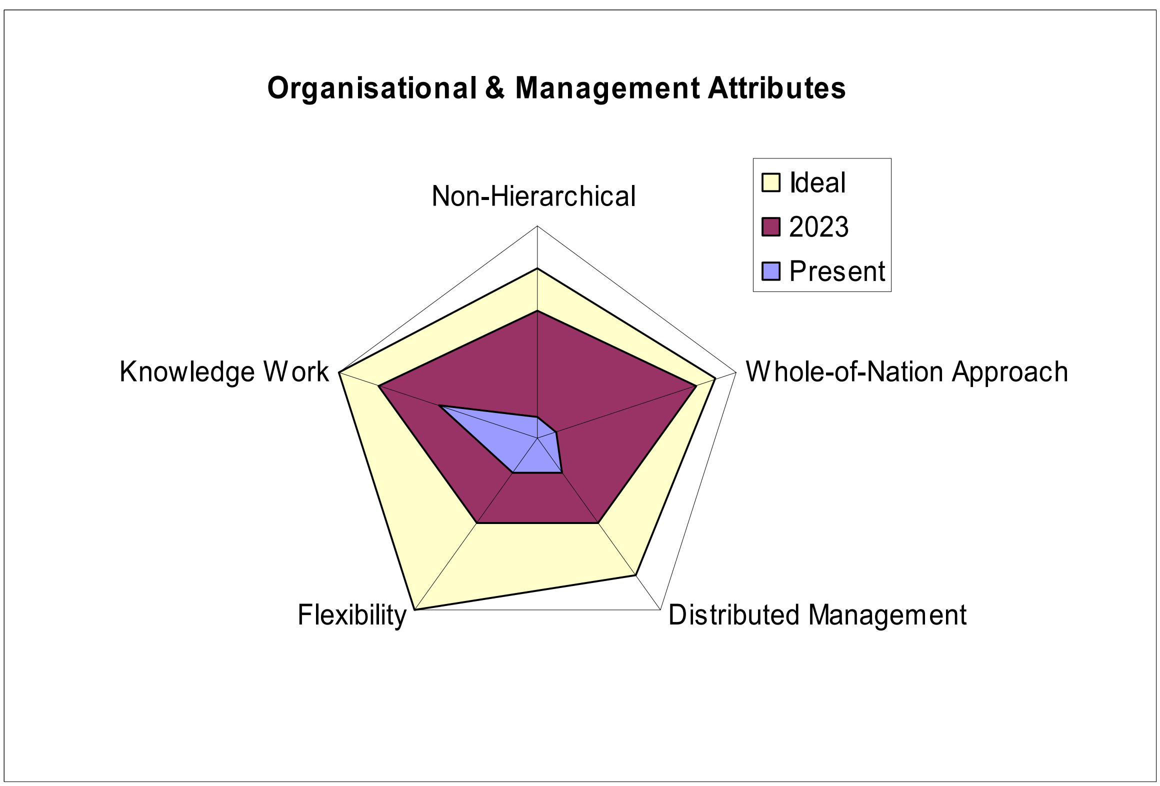

Figure 4. Organisational and Management Attributes of ASBM

8. Conclusion

Developing future ASBM systems is an intrinsic part of developing *Force 2020*, the Australian network centric force of the future. Prediction of future warfare trends and requirements demonstrates the need to evolve ASBM into a system with the NCW attributes of a seamless, geographically dispersed, effectively linked, knowledge enabled and network designed capability. This paper outlines the attributes of an ideal ASBM system, looks at the operational, technical and social drivers that will impact ASBM and then discusses the risks and challenges which will need to be overcome in order to achieve such a capability.

The capability gaps identified in this paper will require significant cooperative research effort within Australia and with allied research groups. While technological developments will proceed rapidly with new sensors, weapons and networking options becoming available, the development of ASBM needs to take into account the ability of the operators and the commanders to cope with the rapid increase in the information supplied. Sophisticated decision aids, information and knowledge management techniques and more flexible organisational structures will be required so that ASBM in 2023 will be accurate, comprehensive and effective. This will provide commanders with a complete awareness of the battlespace and the means to manage and achieve their intent.

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