Wedgetail Evolution: Soaring to Greater Heights?

Geoff Lawrie[1], Scott Capon[2], Philip Cutler[3], Arthur Filippidis[4], Mauro Iob[5], Brett Pearce[6], Timothy Priest[7], Simon Rockliff[8], Mike Skinner[9], Peter Temple[10], Jeff Tweedale[11], Kruger White[12].

[1,3,4,5,6,9,10,11]*Air Operations Division, Systems Sciences Laboratory, Defence Science and Technology Organisation, PO Box 1500, Edinburgh, South Australia, 5111, Australia*
[2,7,8]*Electronic Warfare and Radar Division, Systems Sciences Laboratory, Defence Science and Technology Organisation, PO Box 1500, Edinburgh, South Australia, 5111, Australia*
[12] *Intelligence Surveillance and Reconnaissance Division, Information Sciences Laboratory, Defence Science and Technology Organisation, PO Box 1500, Edinburgh, South Australia, 5111, Australia*

Summary: Wedgetail is the Australian Defence Force's Airborne Early Warning and Control project, which is due for delivery in 2006. This paper presents a view from the perspective of the Project Support Network in DSTO, on paths for capability growth and on the technological possibilities and limitations for growth. Besides technology maturity, an important driver for the decisions to be made on upgrades and the addition of capability will be how Wedgetail is to be employed. AEW&C operations will be influenced by the changing nature of conflict, emerging threats and global trends towards Network Enabled Operations. The Wedgetail mission system is primed for growth since the software architecture is component based and uses distributed computing. Many of the possibilities identified can be implemented in software. Automation of functions in software has much potential, but must be done in a way which has operators and the system working as a team.

Keywords: Airborne Early Warning and Control, electronically scanned array radar, integration, electronic warfare, human factors, interoperability, connectivity, operations research.

Introduction

Wedgetail, the new Australian Airborne Early Warning and Control Capability will be delivered in 2006. It will have a major impact on our ability to conduct surveillance and air defence operations. Not only is it a new capability for the Australian Defence Forces, it is a new type. In many ways, it will be at the technological forefront of airborne surveillance capabilities. Wedgetail evolution will not stop at delivery. Wedgetail's growth has been a consideration since the project was first approved and will continue to receive attention for decades. What is the best path for the evolution of the capability? What are the technological possibilities and where are the limitations? This paper presents a view from the perspective of the Project Support Network in DSTO.

Before looking at the possibilities for the future it is interesting to look at events in the past, which have shaped the present. Here is an anecdote about a decision taken in 1985, by the then Minister for Defence Kim Beasley [2]. Proposals for an AEW&C capability for the ADF were sought and evaluated. Mr Beasley said that the two surveillance systems, the Jindalee Over The Horizon Radar and AEW&C were not in competition, but were complementary. Nevertheless, he took the decision not to proceed with acquisition of AEW&C, saying that Australia could afford to wait before acquiring such a capability. AEW&C capability in Australia would look very different now, had the decision been different.

Time has proved him correct. The competition that some saw between JORN and AEW&C has not materialized. And waiting to decide to acquire AEW&C until 2000 has meant that we have been able to take advantage of major advances in technology, such as Electronically Scanned Array (ESA) radar.

The Operational Context

FORCE 2020 [6] defines the concept of a seamlessly integrated force, which goes beyond the contemporary understanding of “jointness”. It also says that in the force of 2020 we will have transitioned from platform centric operations to network enabled operations (NEO). In response to that guidance, the possibilities discussed in this paper build on the idea that Wedgetail is a node in a network. In many ways, Wedgetail will add impetus to the move towards NEO in the ADF, because of its inherent networking abilities.

Interoperability is an essential requirement for effective NEO within the ADF and with coalition partners. It is a factor, which outweighs many other system performance and suitability parameters, for example, bandwidth. In this sense, interoperability can be viewed as a constraint.

The Physical Constraints

The temptation to talk about technological revolutions and paradigm shifts will be resisted; rather the possibilities discussed here will take the known constraints into account. Constraints such as the inherent limitations of the platform, aircraft payload and available space are obvious limitations, as are aircraft speed, altitude, endurance and power availability. Speed and endurance limitations will govern where and when the capability is employed. Altitude limitations will govern radar performance through line of sight geometry. Power availability will limit radar performance. Electromagnetic compatibility is also a major factor, since the current configuration has nearly 80 antennas including the radar.

Operations Research

Operations Research (OR) has proved valuable in all phases of the project to date. It supported the identification of gaps in surveillance capability and it was used to identify the desirable characteristics for an Australian AEW&C capability and in tender evaluation. It is now being used to support tactical procedures development. It will also be used in the acquisition phase to support test and evaluation. On the completion of Operational Test and Evaluation, Operations Research will still be useful. Analysis using modeling and simulation will arm the decision makers with quantitative measures of the impact of proposed systems on operational effectiveness. OR analyses will also support ongoing operations, and may include,

- Assessments of Wedgetail capability and vulnerability against existing and evolving capabilities
- Monitoring the operational performance over the service life
- Examination of issues associated with coordination and interoperability with coalition forces or civilian agencies
- Further development of tactical procedures

Armchair Warrior Exercises

During the acquisition phase of the project, development of 2SQN TACPROCS has been supported primarily through the Armchair Warrior (AW) series of exercises [5]. These exercises examine the potential tactical employment of the Wedgetail aircraft through a series of scenarios involving human-in-the-loop interaction. Exercise scenarios include operations such as surveillance, air defence, strike, search and rescue, and coordination with ADF forces. In the AW exercises 2SQN operators are provided with a simulated Wedgetail environment in which to test proposed TACPROCS. The testing is further facilitated by the participation of ADF subject matter experts from Air Force, Navy and Army as well as from other agencies.

The Wedgetail Capability Modeling Environment (WCME) and early variants of it, is the simulation tool and suite of models, which has been used as the primary tool for OR for the Wedgetail project. It has been used in Monte Carlo mode for analysis during the Project Definition Study and Initial Design Activity Phases. In the Acquisition Phase to date, WCME has been used in real time operator in the loop simulation mode for Armchair Warrior exercises. It will be deployed to the ASF and 2SQN, as well as DSTO. In DSTO it will continue to be the primary tool used to provide OR support. Consequently, refinement of the suite of models will continue.

The Operational Mission Simulator (OMS), a deliverable under the Wedgetail acquisition contract, is likely to replace WCME as the system of choice for operator in the loop exercises after delivery of the OMS in 2006. Nevertheless, the Armchair Warrior exercises have proved the value of applying operator in the loop simulation to the task of tactical procedures development, prior to the delivery of the actual capability. This idea can be applied to other acquisitions in the future.

Radar

The Wedgetail AEW&C will be the first application of the Northrop Grumman Corporation Multi-function Electronically Scanned Array (MESA) radar. MESA can be regarded as the state-of-the-art for this class of radar. However, the design has been implemented with a strong focus on cost and risk and uses mainly proven technologies, waveforms and algorithms to achieve its strong performance. As with all such designs there is room for improvement through incorporation of more advanced technologies and improved radar signal processing.

The prime drivers for radar capability growth relate to the evolving environment. It is reasonable to assume that the proliferation of technology and know-how in the areas of target radar cross section (RCS) reduction and Electronic Attack may result in the eventual need to improve the performance of the MESA radar in these areas. Secondary drivers may include a broadening of the AEW&C aircraft mission to areas that would provide complimentary coverage to other assets.

Radar detection performance can be improved in many ways. For an airborne surveillance radar like MESA, detection range is a loose function of the product of the average transmitted power, the average effective size of the radar antenna aperture and the time taken to scan the surveillance volume (all other factors including signal processing losses being equal). As a consequence of this so-called “power – aperture – time product”, the classic approach to increasing the detection range of a surveillance radar is to either increase the transmitted power, to increase the size of the antenna or, to slow down the radar scan time. The first two approaches are not particularly practical for the MESA radar as the antenna aperture is constrained aerodynamically and the power output of the radar is constrained by the aircraft prime power system. The approach to performance improvement needs to be in the areas of intelligent control of the radar time line and in decreasing system losses through advanced waveform and signal processing techniques.

The adaptive optimisation of radar dwell times, waveforms and signal processing to the radar operating environment is a burgeoning area of radar research. The outcomes of this research work may influence the direction in which MESA could grow. By optimising all possible parameters to suit the operational and natural environment, radar performance can be maximised. For example, the radar waveform, dwell and revisit strategy could be optimised on the basis of target density and ground clutter environment such that the performance was not limited in a low density, low clutter environment as it would be for a fixed set of waveforms and other parameters designed for operation in a worst-case high density, high clutter environment.

A specific example of signal processing improvement would be the incorporation of Space Time Adaptive Processing (STAP). This is a technique for simultaneously reducing the effects of ground clutter and other interfering signals using two-dimensional adaptive filtering. Incorporation of STAP would require hardware and software changes to the MESA radar as more receiver channels and higher signal processing capacity would be required. Many implementations of STAP are not yet realisable as the computational performance required to perform the filtering functions in real time exceeds that of currently available computing hardware. However, it is likely that during the long service life of the Wedgetail system, these and other signal processing techniques will become realisable at reasonable cost.

The MESA IFF function has the capacity to be improved to incorporate new interrogation modes as required for interoperability and national reasons. The incorporation of new and improved IFF modes must be in concert with the general drive towards improved combat identification within the ADF. Additionally, intelligent scheduling of the IFF function to suit the operating environment may yield improvements in range and update rate performance.

Infrared Search and Track

Airborne Infrared Search and Track (IRST) systems are capable of detecting fighter aircraft at ranges in excess of 50 nm (dependent on altitude, atmospheric conditions and aircraft aspect), with high accuracy in azimuth and elevation measurement. By integrating the IRST detections with other sensors, such as radar or ESM, within the Multi-Sensor Integration function, a more accurate target track could be generated. In addition, the high angular resolution provides an increased capability to separate targets that are unresolvable by the radar system [1][4].

In addition to its IRST detection capability, the systems could be operated in a single target track mode, providing higher resolution imagery for close-in target identification, either automatically or manually.

IRST systems require significant image processing capability. An assessment would be needed to determine whether this could be carried out using the existing processing capability, within the Mission System, or whether additional hardware would be required.

Electronic Warfare

The current fit of the Electronic Warfare equipment to the Wedgetail aircraft is the ESM system, an EW controller, a missile approach warner, directed IR countermeasures equipment and chaff and flare dispensers. This is seen as providing a robust situational awareness and EW self-protection (EWSP) capability to underpin the concepts of operation of the aircraft in the threat environment anticipated for the first decade subsequent to introduction to service.

The evolving environment over the lifetime of the aircraft and the nature of the missions to which it is allocated will drive future upgrades to the Wedgetail platform in the Electronic Warfare area. While the CONOPS for the aircraft will seek to limit the nature and type of threats that the aircraft is exposed to, advances in threat and missile systems will drive the requirement for additional EWSP capability over the next 20-30 years. Threats may be IR-guided ground-launched SAMs, including MANPADS with higher energy motors capable of reaching greater altitudes, and improved vehicle mounted systems, including possible adaptations of air-air missile variants. Long-range radar guided "AWACs killers", either air- or land-launched, will likely be a feature of modern warfare as the opponents attempt to degrade adversary capability to maintain situational awareness in the battlespace.

Various options for EW upgrades may be considered as a consequence of any analysis of the types of future threats likely to be employed in the areas in which the aircraft may be deployed. Additional on-board transmission antennas would widen the scope of the possible ECM techniques that could be employed, although at greater cost and complexity in integration onto the Wedgetail platform.

Evolution of IR missile seekers will necessitate further upgrades in optical countermeasures. As part of the on-going sustainment of the AEW&C survivability, new flare types which offer improved effectiveness against IR-guided threats with advanced ECCMs are likely be acquired and cleared for use from the Wedgetail aircraft. Combinations of tactics and coordinated optimal use of the existing electro-optic countermeasures will be developed to minimise threats from advanced IR seeker types in the future. New laser variants offering improved performance may be retro-fitted to upgrade the DIRCM capability in future years.

From the experience of other programs, upgrades to ES equipment and databases seem inevitable within about 10 years of entering service. Obsolescence issues and improvements in commercially available processing chips are likely to drive ESM processor replacement at regular intervals through the life of the airframe. Some new ES capabilities may be inserted incrementally as part of new software releases: others will require hardware modifications and will be a more major upgrade exercise.

Another technology insertion that may be considered for EW applications on the Wedgetail aircraft is use of RF photonics. Photonic technology insertion is very scalable; from a straight-forward RF cable replacement that will provide weight, EMI/EMC and frequency-extension benefits over current EW systems, through to advanced RF photonic insertions, in which the architecture of the ESM system can be greatly simplified, providing performance, weight, maintenance and through-life cost benefits.

In addition, photonics signal processing can be utilised to process data from sensors and systems at a combined rate and volume that is impossible or impractical with pure electronics. This provides the ability to implement signal processing topologies that are difficult to realise with conventional electronics systems, thereby opening up the potential for completely new functionality while increasing robustness and reliability without sacrificing weight or system complexity.

In short, the EW area is never static, the EW capability must evolve to keep pace with the changing threat environment, and it is inevitable that upgrades will be required.

Interoperability and Connectivity

The AEW&C will have an operational communication capability, which will ensure effective integration into the ADF and interoperability with allied forces. It will provide dynamic transfer of surveillance information, co-ordination with command authorities, liaison with co-operating forces and control of assigned forces. Specifically, it will support operations in the HF, VHF, and UHF bands (Line Of Sight and MILSATCOM).

The Tactical Digital Information Links (TADILs) on the AEW&C will be Link-11 and Link-16, which will provide the tactical advantages of improved situational awareness, improved real-time weapon co-ordination among land, surface and other airborne units, secure jam resistant communications and interoperability with joint and international forces. The AEW&C can provide beyond line of sight capability as it can be used as a relay for various link networks. Capable though it will be at delivery in 2006, there are many emerging possibilities for upgrades to Wedgetail communications.

Co-operative Engagement Capability (CEC), Common Link Integration Processing (CLIP) and the Joint Tactical Radio System (JTRS) with the two communication channels in development Wideband Networking Waveform (WNW) and Tactical Targeting Network Technology (TTNT) are some new and emerging technologies that may be considered for Wedgetail in the future.

Co-operative Engagement Capability (CEC) is a data fusion system, which consists of hardware and software that shares radar data on air targets between platforms. It generates a common real-time fire control quality track picture hence improving Anti-Air Warfare capability. CEC might have been overtaken by newer technologies at the time of the first major upgrade for Wedgetail.

The Joint Tactical Radio System (JTRS) [13] is a common family of software definable radios. JTRS is designed to be scalable, has high capacity, supports internet protocol (IP) routing and tactical internet protocols, has line of sight (LOS), beyond line of sight (BLOS) capability, and will reduce RF equipment configuration overheads. The full rate of production of the radio is planned in 2008 and will be backward compatible with over 30 current waveforms.

The JTRS Wideband Networking Waveform (WNW) will produce the future common tactical data link waveform. It will generate numerous current and future waveforms. WNW is a communication channel, IP based radio waveform development project within the Boeing-led JTRS Cluster 1.

Tactical Targeting Network Technology (TTNT) [14] also for use over JTRS, is the next generation form of weapon data link technology that interoperates with WNW to improve weapon accuracy, flexibility and efficiency. Sensors correlate data from multiple platforms to geo-locate (using 3 platforms) the target. The Rockwell Collins TTNT communication channel, IP based radio waveform has emerged under a contract with the US Defence Advanced Research Projects Agency (DARPA). It has low latency, high throughput and uses dynamic networking (ad hoc). TTNT allows platforms to receive multiple messages quickly and simultaneously. Comparisons with Link-16 are that it cannot send voice and data messages simultaneously and cannot transmit video.

The Common Link Integration Processing (CLIP) is a common software module providing a variety of Tactical Data Link functions that can be tailored to individual platforms and can be hosted in a range of architectures. The advantage of CLIP is that it isolates platform based combat systems from future changes to Data Link standards [15]. CLIP may possibly be considered in future upgrades of the data link module (Data Link Infrastructure, (DLI)) currently being developed specifically for the AEW&C. One of the benefits CLIP may have over the DLI is its open architecture.

In the nearer future Wedgetail could incorporate Variable Message Format (VMF). VMF (unlike Link-11 & Link-16) is not tied to any specific radio or processor environment and is suitable for near-real-time data exchange in bandwidth constrained combat environments. Its advantage is that it shares data elements with Link-16 and the network can use Commercial Internet Format (TCP/IP), meaning it can be a participant in the “Tactical Internet”. VMF will allow Wedgetail to extend its Force Coordination role.

Link-22 may in the future replace Link-11. Link-22 is a secure ECM resistant Tactical Data Link, which will complement Link-16 with the F series Message Standard. It has improved capacity, robustness, error detection and correction and can have a maximum of 4 networks running concurrently with up to 120 participants per network. Each network can achieve ranges up to 1000nm.

Looking further into the future, THOR is work on a mobile, free space optical network (sponsored by DARPA under a USAF contract), which brings broadband data into and out of the theatre of operations using high power lasers and beam steering. It has high capacity and is secure. However it has poor cloud penetration and so requires network management to work around this limitation. Future radio links on Wedgetail may be complemented with THOR.

Multi-Sensor Integration

The Wedgetail capability has multiple onboard sensors and will communicate with multiple assets and agencies. An automated Multi-Sensor Integration (MSI) function integrates the data from local and remote sources into a single track per target and determines the correct identification and classification of each track. Situation and Threat Assessment (S&TA) of the compiled track picture of multiple targets in the surveillance volume is necessary to determine appropriate actions for controlled assets, including platforms and sensors. The flexibility of sensors such as electronically scanned phased array radars can be managed in order to develop and maintain the track picture in response to mission objectives.

It is clear that upgrades to any of the data sources for MSI, including local sensors and remote sources, must consider the impact on MSI. If necessary, the MSI capability will require modification to accept new and different types of information. These modifications may extend from simple changes to interface messages or more complex changes such as tuning of target model parameters and algorithm enhancements. Indeed, as experience is gained with the employment of Wedgetail's new sensor suite, modifications to MSI may be considered without upgrades to the data sources.

Research is active in the fields of Tracking, Identification, S&TA and Sensor Management. Coupled with improvements in computing power, MSI algorithms currently under research can offer enhanced function and performance. For example, most tracking algorithms in today's fielded systems operate under linear assumptions for the sensor measurement process and the target state evolution. When a linear assumption is a poor approximation, tracking algorithms that do not rely on linear assumptions can provide improved track accuracy and continuity. Improvements to the data association algorithms will also improve tracking performance, particularly in dense target scenarios and clutter environments.

An important requirement of the Wedgetail system is the ability to interoperate with other agencies and assets and to conduct Network Centric Warfare. As new methodologies for communication of information become available, new ways of processing the data will be required. MSI tracking algorithms aboard the Wedgetail platforms will require corresponding changes to ensure that appropriate mission information is presented to the user community.

Traditionally, tracking and identification are treated as separate, serial processes. Future upgrades to the Wedgetail MSI may consider performing the tracking and identification functions jointly so that information about the target classification can directly aid the tracking process, and vice versa. Prior information about the constraints of a particular target class may be used to better determine candidate reports to associate with a track.

Enhancements to the S&TA function could include exploiting the relationships between tracks and incorporating prior information about force structure to reason about the behaviour and intent of opposing force assets and to recommend appropriate actions. Various types of uncertainty must be managed in performing S&TA. Possible upgrades to the Wedgetail S&TA function include improved algorithms for reasoning in the presence of uncertainty and treatment of additional track or other parameters upon which S&TA is performed.

Radar/IFF Sensor Management is one of the key areas in which significant capability enhancement may be achieved for the Wedgetail AEW&C. Electronically Scanned Phased Array Radars permit flexibility in managing the sensor resources according to system requirements. Parameters that can typically be varied include beam direction, beam dwell time and time interval between revisits. Potential enhancements may include: the ability of the MSI to determine optimal track revisit times based on the radar performance, required track accuracy, track separation, track manoeuvre state and threat level; and the automatic generation of surveillance sector requests in response to cues from other sensors and operator inputs. New or enhanced sensors may also present opportunities for improving system performance through Sensor Management.

Decision Support Systems

The Boeing developed Wedgetail AEW&C incorporates decision support systems (DSS) within the Mission Computing Subsystem (MCS) to assist operators perform the roles of Track Identification and Classification (ID) and Situation and Threat Assessment (S&TA). The DSS have been implemented in order to assist operators to gain and maintain situational awareness (SA) of what may be a rapidly changing surveillance picture of the controlled environment. Improvements to the DSS might include:

- the incorporation of advanced information processing (AIP) technologies that incorporate learning capabilities and make greater use of the information available to the mission system particularly from data links;
- more advanced sensor management based on increased feedback from the ID and S&TA processes; and
- the ability for operators to play out scenarios in real-time during a mission.

The existing DSS provide recommendations to the operators based on rules and thresholds set by the operators, either prior to or during each mission, based on the expectations for the mission. During the mission the DSS work largely independently of the operators and provide recommendations that the operators can choose to employ or ignore. The DSS are therefore required to be manually reconfigured if instances occur where the configuration employed for the mission is not satisfactory. Our goal is to provide an integrated, man-machine, team based approach with the operator retaining supervisory control. A DSS that works as a team, led by the human (pilot or crew), with the machine as a subordinate associate or assistant, all sharing responsibility, authority and autonomy over many cockpit or mission system tasks, has many advantages. Technologies such as intelligent agents provide a framework for teaming which could form the basis of future enhancements.

The existing DSS currently use limited amounts of the information available from data links. Information such a weapons management and fuel management would allow better more effective automated battle management to be undertaken.

Given the flexibility offered by the Wedgetail’s MESA radar, an area that is seen as offering a large potential increase in the operational effectiveness of the aircraft is a more advanced automated sensor management system. Improved integration incorporating more advanced feedback from the DSS to the sensor manager will be explored to determine gains in the utilisation of the sensors. Automated sensor management is expected to allow the sensors, primary radar, IFF and ESM, to be managed more effectively in order to optimise coverage and reports. Management approaches can be based on areas not well covered, the tracks currently being monitored and on the importance of the tracks.

With improvement in simulation technology, processing power and sensor modelling, opportunities may exist for the DSS to offer the ability for operators to concurrently run real-time simulations to provide predictions of the outcomes of decisions or events. Such capabilities could be used to provide guidance where decisions offer questionable outcomes or highlight unforeseen problems that may arise given a particular decision.

Many challenges result as increasing levels of automation are built into human-in-the-loop systems. Challenges are both technical and psychological in nature. Increased automation generally requires additional computational resources. Some DSS functionality is already limited due to the available resources within the aircraft mission system. Studies to look at the ability to provide networking capabilities within airborne mission system to computers external to the mission system need to be conducted to assess the ability to provide additional processing without affecting current system performance. Task allocation between operators and machine has become an increasingly difficult design challenge especially when flexibility is needed to handle rapidly changing operational situations and to avoid the risk that decisions are locked into a specific automation design. Earlier mistakes in automation have emphasised the importance of a correct balance between the control and monitoring tasks especially for the human member of the team. In order to maintain overall efficiency and safety, it has been suggested that the human should stay involved in all critical control tasks and be presented with information in a format that is human friendly. Automation must therefore cater for intensive communication, management and coordination between the different members of the human-machine team. The operator must be able to retain an understanding of the state of the automated system and be able to trust the outcomes of the system. Improved teaming and confidence are critical to reduce the independence of the operator and system to improve the workflow and thus reduce workload [10,11,15,19].

Mission Computing

The Mission Computing Subsystem (MCS) is the critical subsystem at the heart of the Wedgetail mission system. The MCS provides the mission processing for sensor fusion, sensor management, battle management, communications management and system control. The MCS also includes the mission consoles and Flight Deck Tactical Display with associated display processing. The evolution of the Wedgetail platform capabilities discussed in this paper will require significant upgrades to the MCS processing.

Wideband technology is a vital contributor to Network Centric Warfare but will greatly increase the amount of information that must be processed by the MCS. Software programmable radio technology (such as that provided through the Joint Tactical Radio System (JTRS) program) opens the possibility of innovative approaches to communication requiring extensive software support. New sensors and sensor processing algorithms will bring new demands on processing. Ongoing improvements to tracking and sensor fusion algorithms (such as Multi-Hypothesis Tracking) and the Human-Machine Interface will further stretch computing resources.

To support these enhanced platform capabilities the MCS will undergo updates throughout the Life of Type of the platform. Traditionally mission systems have been upgraded in major increments, such as mid-life updates. The upgrade philosophy for

Wedgetail is ongoing minor increments in capability (Pre-Planned Product Improvement) to allow capability enhancements more in line with operational requirements. This approach of growth in place of wholesale replacement has guided the specification and design for the MCS.

The need for Mission Computing growth in the Wedgetail platform was recognised from the start. The subsystem has a specified limit to the use of the available processing throughput, bus bandwidth, memory and storage capacity at delivery. This will allow post delivery enhancements to extant processing algorithms, and increased processing without the need for additional hardware. The MCS hardware had to be based on upgradeable technology components, which comply with commercial or military standards. This includes processors widely used across industry, which have a planned and demonstrable upgrade path, and the use of open architecture busses. Operating systems and application software had to be tolerant to changes in hardware configuration and selected based on long-term support and availability. In addition aircraft reserves in space, power, cooling and weight were specified to allow for processing hardware upgrades.

The Mission Computing hardware is designed for growth. With the exception of the mission consoles, all of the hardware components are based on COTS components.

The Mission Computing software is also designed for growth, utilising a flexible open system architecture. The use of COTS and standard interfaces allows future upgrades and technology insertion. The Solaris operating system is widely used and supported by Sun Microsystems, allowing straightforward upgrades. The core architecture is built on a distributed real-time Common Object Request Broker Architecture (CORBA) and a framework allowing components to be dynamically deployed across the available processors. This framework provides a modern multi-threaded and event driven architecture. Components have precisely defined interfaces that allow components developed in any language and by any developer to be integrated into the distributed system as long as the components conform to the framework patterns. Dynamic component deployment is managed by clustering software that can dynamically balance load across the available processors and manage redeployment in the case of failed software or hardware. The use of standard interfaces such as Ethernet and MIL-STD-1553 allows the addition of new equipment or substitution of equipment without extensive software redesign.

Together the MCS hardware and software design provides a flexible and modular architecture that provides a growth path for processing in support of through-life upgrades for the Wedgetail platform.

Future Interface Technologies

The future networked battlespace will lead to an explosion in the information available to Wedgetail operators. While such an information-rich environment has the potential to improve the operator's decision making and enhance their situation awareness, there is the danger that the flood of information may overwhelm the operator. In addition, the demands of time critical targeting (TCT) will place pressures on operators to make rapid decisions on the basis of this information. Operators will also be increasingly required to operate within, and coordinate, flexible, adaptive, distributed teams, in joint and coalition operations.

Advanced interface technologies to assist the operator to function effectively in such an environment (reduce workload; improve performance) are being explored under Project Arrangements with the United States Air Force Research Laboratory, Human Effectiveness Directorate. Three main areas are being investigated: improving communications systems (to increase communication throughput, accuracy, and reduce workload), building the tactical picture (improving the individual operator's performance via workstation enhancements), and sharing the tactical picture (improving team performance through collaboration technologies). The most promising interface technologies from these investigations will be considered further for Wedgetail upgrades.

The AEW&C environment is communications-intensive. Laboratory research [8] has demonstrated that spatially segregating communication channels (digitally filtering speech streams so that they appear to emanate from distinct locations in space over stereo headsets) improves the intelligibility and reduces the workload associated with monitoring multiple channels. Improved radio monitoring was also confirmed when the technology was tested in an AEW&C context [9]. The first operational communications switch with an embedded spatial audio capability was delivered to the 98th Range Wing at Nellis AFB in 2003. While development effort would be required to incorporate this technology into the Wedgetail AMS, an assessment of integration issues indicated that no major architectural changes would be required. The technology has demonstrated benefits that are applicable to Wedgetail and there are no technical showstoppers.

Direct Voice Input (DVI) permits an operator to control workstation functions by speech commands. DVI has been demonstrated, with normal communications loads, to reduce the time and workload required to carry out a range of tasks [7]. Some operator functions may benefit from insertion of this technology.

Limitations to operator display space on Wedgetail has the potential to introduce high memory loads, increase the need for paper documents, and increase the time away from the primary situation display, reducing situation awareness. Head mounted displays (HMD) and multi-layer displays (MLD) technologies aim to increase available display space, but also offer the promise of better integration and management of multiple information sources, increasing operator efficiency and situation awareness through the more effective display of visual information. While there is the potential to expand display space and enhance its management through HMD technologies, these technologies could interfere with crew interaction and coordination if not appropriately designed. Additionally, the expanded display space around the head makes the use of traditional input devices such as keyboard and mouse more difficult, so the use of DVI or other alternative control technologies are indicated. The application of HMD technologies to command and control contexts, and the AEW&C environment in particular, has not been fully investigated.

MLD technologies (based on two superimposed LCD layers) offer the potential to reduce clutter, improve tracking and detection, and facilitate the integration of multiple sources of information. Initial evaluations of these displays for basic tracking tasks have not demonstrated any advantages [3]. While the benefits of these visual display technologies are yet to be confirmed, an assessment of their integration into the Wedgetail AMS indicated no major difficulties.

While teamwork has always been at the heart of AEW&C operations, network enabled operations add complexity and a more dynamic character to this teamwork dimension. Collaboration technologies will be required to support the coordination of larger, more distributed teams and to develop the shared situation awareness that will underpin effective net-centric operations. Tactical datalinks will provide one means of sharing time-critical information and developing this awareness (of the battlespace and the commander's intent), but a comprehensive investigation of collaboration technologies will be required to identify the optimum configurations for sharing information and making efficient and effective tactical decisions. Existing technologies such as video conferencing, text messaging, file sharing, shared interactive information spaces, opinion and polling tools, automated workflow and mission timelines, and a range of automated decision support tools, all show promise [17], but these technologies will need to be evaluated for an AEW&C context.

Team Training

While effective display, collaboration, and decision support technologies will assist the Wedgetail operator to function in an NCW environment, the development of training interventions for this environment will also be essential. The Wedgetail training simulators will need to evolve to capture the characteristics of the future networked battlespace. Given the requirement for increased joint and coalition operations, distributed mission training capabilities will be crucial for effective and efficient training. The Wedgetail simulators and training infrastructure will need to develop enhanced DMT capabilities to meet this requirement.

But training for NCW must also involve more than simply exposing operators to the networked battlespace. Given the importance of communication, collaboration, self-organisation, and adaptive teamwork, the operator's readiness for NCW will be increased through training that is focused on enhancing their ability to (i) facilitate adaptive teamwork, (ii) make decisions in dynamic and uncertain situations, and (iii) plan and critically review their actions. The training approach employed will need to capture these requirements.

Human Factors

Cognitive Work Analysis (CWA) [12,18] is gaining momentum as an approach for the analysis, design, and evaluation of complex sociotechnical systems. CWA consists of five distinct phases of analysis: (1) Work Domain Analysis identifies the purposes, values and priorities, functions, and physical resources of a system; (2) Control Task Analysis identifies the activity that must be executed by a system; (3) Strategies Analysis identifies how the activity can be carried out; (4) Social Organisation and Cooperation Analysis identifies who can do the work and how it can be shared; and (5) Worker Competencies Analysis identifies the perceptual and cognitive capabilities of workers that are required for performing the work described in the previous phases. Applied as a tool to design, CWA provides system designers the insight into how to create tools to effectively support human work. In the early stages of AEW&C acquisition, CWA was used for tender evaluation and crew concept definition. In addition, CWA may be used to contribute to many aspects of post-acquisition support and future growth.

The Human-Machine Interface (HMI) solution for the Airborne Mission System is based on re-use of a legacy HMI solution with modification and addition of Wedgetail-specific system functionality. Moreover, the Wedgetail Concept of Operations (CONOPS) continues to evolve, and will continue to do so beyond system acquisition, test and evaluation, and into service. Accordingly there will be much scope for advancement in such Human Factors areas such as HMI design.

For example, the second phase of CWA, Control Task Analysis is the analysis of what needs to be done in a work domain. Control Task Analysis serves to identify the cognitive demands of a work domain, such as the identification of the information needs, situation analysis, goal evaluation, planning and procedure execution to achieve a particular decision task. Moreover, the analysis and identification of operator Strategies – the third phase of CWA – supports the various strategies that operators usually adopt to perform any one task, and thereby supports effective system control by operators of various expertise.

Both CWA phases may inform the development of more advanced HMI support tools for the decisions operators have to perform. For example, more advanced automation concepts may be developed based on the identification of such decision making requirements and thereby, the allocation of functional tasks to operators and the system.

Conclusions

There is a wealth of possibilities from a technical perspective for growth in Wedgetail, with many systems and technologies in various states of maturity. Besides technology maturity, an important driver for the decisions to be made on upgrades and the addition of capability will be how Wedgetail is to be employed. In turn, AEW&C operations will be influenced by the changing nature of conflict, emerging threats and global trends towards Network Enabled Operations.

Operations Research will continue to inform the decision makers on the operational effects of added capability. The modeling and simulation suite used will itself continue to mature and add quality to the advice generated by analysis.

The performance of the MESA radar must be improved over time to match the evolving threat environment. It has the capacity to grow in performance through more intelligent time line use and, environmentally adaptive waveforms and signal processing. Additional modes of operation may need to be incorporated into both radar and IFF functions as operational needs evolve. The modern, COTS, high-level software language design of the radar system should allow such improvements to be affordable.

The Wedgetail mission system is primed for growth since the software architecture is component based and uses distributed computing. Many of the possibilities identified can be implemented in software. This applies as much to radar as other sub systems. Automation of functions in software has much potential, but must be done in a way which has operators and the system working as a team.

Regardless of the growth paths chosen, DSTO will be working in partnership with the RAAF and DMO, to ensure that Wedgetail continues to soar to great heights.

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