Application of Network Centric Warfare Concepts to a Land-Air System – an experimentation approach

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Abstract

This paper describes the development of concepts for a military system of systems comprising a variety of land and air assets integrated via network centric technologies and appropriate procedures. A methodology is being applied which aims to coevolve the technology and human aspects of the system of systems. The methodology features synthetic environment based experimentation with a system concept demonstrator, which is constructed from an appropriate mix of simulations, real hardware and software, and humans in key decision making roles. The problem issues and chosen metrics and scenarios determine the fidelities of the representations of the components of the concept demonstrator. This paper illustrates this approach with reference to Exercise Prowling Pegasus, a synthetic environment experiment, which was a stage in the spiral development process implicit in the methodology.

1 Introduction

In an attempt to demonstrate that the coordination and synchronisation of force elements of a Land-Air System-of-systems (LAS) could be effectively achieved with the use of Network Centric Warfare (NCW) concepts, we have constructed a system concept demonstrator (SCD) and exercised this in a Synthetic Environment (SE). The LAS is a synergism of platform components, C4ISR technologies and the people and procedures. Traditionally the formation, tasking and command and control (C2) of Battlegroups, such as the LAS, has been accomplished by following standardised procedures involving hierarchical lines of command and communication. This process can lead to large time delays between task initiation and required effect and also can impose a lot of rigidity to the mission plans. As a consequence, air strike missions in support of land operations, for example, are not very responsive and tend to be restricted to targets with fixed location. There is considerable potential for NCW technology to change this situation but any introduction of technology must be accompanied by the development of new procedures and operational doctrine. We have previously described (ref 1) a system-of-systems (SoS) development and evaluation methodology, which is a combination of system architecting, Operations Analysis and iterative experimentation using synthetic environments. This methodology involves the development of a SCD and immersion of this in a SE, in order to develop, refine and evaluate concepts of operations and tactics, techniques and procedures (TTPs) exploiting the new features of the SCD. The SCD needs to be a suitable mix of models and simulations, real hardware and software, human players, organisations, and procedures. Representation of the various components of the SoS in the SCD is ideally determined by the sensitivity of the overall metrics to the fidelity of the representation, but availability, feasibility and cost of possible representations will also be major factors. The SoS representation is also influenced by the issues chosen for study and the scenarios developed to address these. Due to the difficulty in modelling complex human decision processes and the major part these will play in the Land-Air SoS, key decision-making roles in the SoS are played by real people. This requires some realistic representative interfaces between the humans and the rest of the experiment such as existing or prototype Command Support Systems. A further aspect of the SCD is the interfaces to the interaction environment, which need to be realistic enough to adequately represent the flow of information between the SCD and the environment, but also allow access for measurement of parameters of the system during the experiment for construction of the various metrics required for the system analysis.

We have just completed a SE based experiment called Prowling Pegasus which aimed to assist the development of a Land Air system concept for the Australian Defence Force. This paper describes Prowling Pegasus against the framework provided by the methodology of reference 1. Some results from a first analysis of the experimental data are presented and conclusions drawn as to the potential benefits of Network Centric technologies and procedures to the Land Air system. Further insights into the conduct of SE based experiments were gained and these are discussed.

2 Methodology

The methodology described in reference 1 is essentially an iterative development process whereby a demonstrator of a SoS is constructed, experimented with and then modified in order to coevolve the technology and human procedural aspects of the SoS. The aim is to produce the SoS synergies such that, as a penultimate step in the process, an evaluation can be made of the true value of a new SoS rather than of an assemblage of new components with old procedures. What is different about our methodology is the potential to rapidly accelerate the coevolution process and to significantly reduce the overall cost. This is achieved by a combination of the use of a SE to represent most of the own and all of the enemy force in the conflict environment and, the integration into this SE of a SoS concept demonstrator. The use of real humans immersed in the SE is a vital part of the methodology as it is these that make the major contribution to the development of new procedures better suited to the NC technologies so as to elicit the SoS emergent behaviour.

In reference 1 the methodology was described as consisting of four phases. This paper is concerned with the first three of these and the application to the Land Air System concept development. In summary, the methodology consists of:

Phase 1. Problem definition and development of:

- Issues
- System of systems concept to address issues
- System of systems architecture
- Metrics of system's ability to satisfy issues
- Scenarios to provide context and stress ability of system to satisfy issues

Phase 2. Development of system of systems concept demonstrator (SCD)

- with fidelities of component representations chosen on the basis of sensitivity of chosen metrics

Phase 3. Immersion of SCD in synthetic environment

- with play-out of scenario
- collection of data and analysis to populate measures of effectiveness
- feedback to modification of system concept

Phase 4. System of systems robustness.

- Model SoS in lower fidelity wargame (Janus or CASTFOREM)
- Evaluate against same metrics but in a variety of different scenarios
- Feedback to refine system concept and further iteration of development cycle.

3 Problem definition and metrics

The problem addressed in the Prowling Pegasus experiment was the formation and command and control of a BattleGroup (BG) with significant aviation capabilities working in a coordinated fashion with some specific ground elements. The resulting SoS is what we call the Land Air system-of-systems (reference 2). The hypothesis to be tested was that Network Centric technologies and appropriate procedures would increase the effectiveness of the LAS and possibly enable new SoS capabilities. To test this hypothesis the technical aspects of the system had to be designed and appropriate procedures developed. The basic concept was that all members of the BG could share information on blue force positions, status and mission plans and, detected red force positions, status and projected red course of action. All this would be presented in a visually intuitive way (3d presentation) superimposed on a representation of the terrain such as to enable shared situation awareness, enhance decision-making, facilitate communication of commander's intent and orders and allow real-time mission monitoring. The sharing of information digitally would be augmented by voice communication to better assist knowledge generation and sharing. A representation of the LAS concept is given in Figure 1, which is an OV-2 product in the notation of the US DoD C4ISR Architectural Framework (ref 3) and produced with the Ptech tool (ref 4). However the SoS also involves the human aspects of cognition and decision-making together with procedures developed to extract the potential benefits of the technology. An initial set of new procedures was developed in a separate seminar involving both military and technical experts and the intent was to develop these during the Prowling Pegasus experiment and in later iterations.

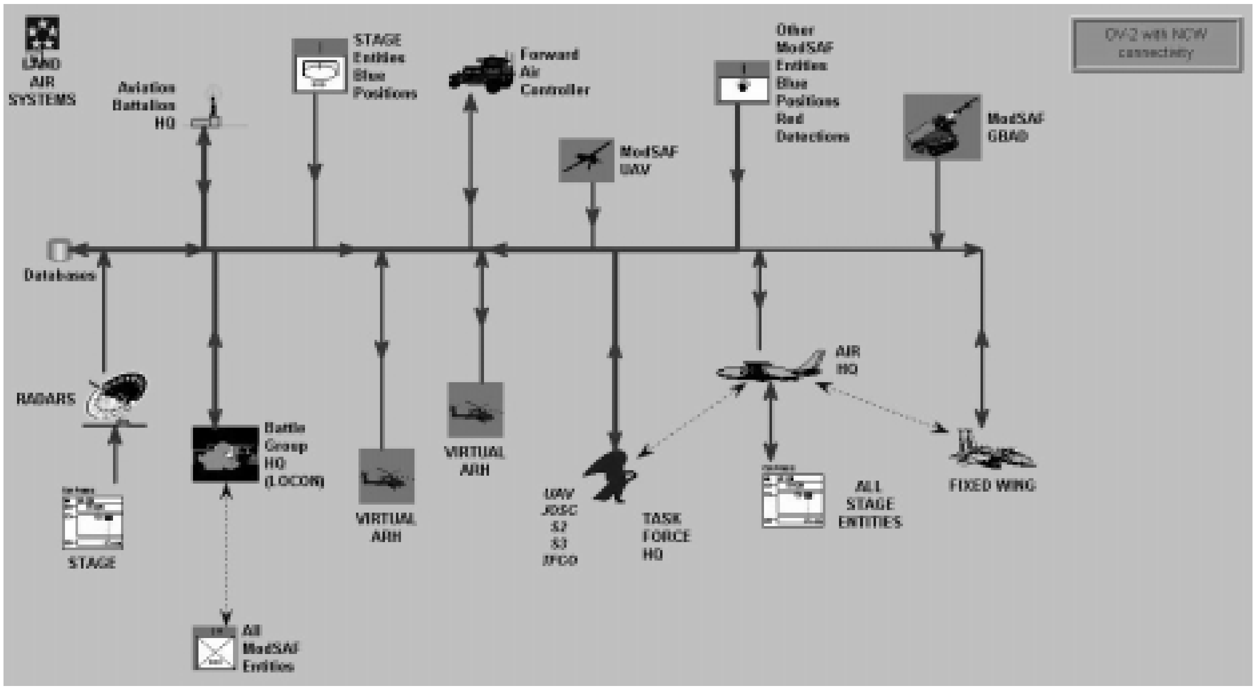

Figure 1. Node connectivity of the Land Air System concept (OV-2)

As mentioned above, metrics are important to several aspects of the methodology. A hierarchy of measures has been developed for the LAS development following the guidance given by the Military Operations Research Society (ref 5). This hierarchy is described in table 1. At the highest level, Measures of Force Effectiveness, MoFEs, provide a measure of how well the overall mission intent was satisfied. Such measures are necessarily scenario specific and can be derived from analysis of the articulated intent. As an example of such an analysis, the scenario for Prowling Pegasus required the blue force to expel an enemy force from a town and to destroy them in detail outside the town. Implicit in this intent is a requirement to minimise civilian casualties and collateral damage in the town and to prevent the enemy from continuing to fight once removed from the town. A total of three MoFEs can be shown to address both the stated and implied intent. These are: total time to expel all enemy from town; the time integral of enemy capability in town; and the numbers of enemy destroyed outside the town reduced by (weighted)[1] numbers escaping and (weighted) numbers destroyed in the town. At this level (and all levels) measures of cost are also required such that cost benefit analysis can be performed for capability acquisition processes. The high level costs identified are; overall capital value of the force; losses to force; civilian losses.

At the next level down are the MoEs describing the effectiveness of the LAS. In a similar way to the higher level, the role of the LAS as articulated in the intent communicated to the LAS BattleGroup commander is analysed and measures of effectiveness constructed. For the Prowling Pegasus scenario, the role of the LAS was to locate and destroy prioritised enemy targets outside

[1] With weightings assigned in accordance with subject matter expert judgement.

town. A simple measure is the number of targets destroyed which can be attributed to the LAS either directly or through its target acquisition for a 3rd party shooter. This MoE is then the ratio of numbers destroyed due to the LAS to the total numbers destroyed, with perhaps some reduction due to the (weighted) numbers of assigned targets not destroyed. Costs at this level include measures of: capital value of the LAS; losses to the LAS; fratricide due to LAS; civil casualties due to LAS; and collateral damage due to LAS. There is also the possibility that the use of the LAS could have an indirect effect on enemy tactics and hence influence the overall operation as reflected in the MoFEs. Such possibilities underscore the importance of baselining with and without new capabilities such that relative improvements can be assessed.

It is at the next level down that the impact of the Network Centric concepts begins to be apparent and directly measurable. Aspects of the LAS that directly impact its effectiveness are rate of targeting, and probability of kill. Rate of targeting involves the whole process of surveillance, reconnaissance, target acquisition and target hand-off and all of these have the potential to be significantly enhanced by NCW concepts. The Prowling Pegasus experiment essentially held the probability of kill once targeted at a fixed level so the one MoE at this level that varied in the experiment, is the rate of targeting. In comparison experiments, the knowledge of the enemy prior to tasking of the LAS, is the same for all cases. Costs at this level are essentially the vulnerability of the LAS and this is related to: knowledge of threats; tactics employed to avoid known and potential threats; and risk accepted. All of these are also potentially affected by NCW concepts. The measure of vulnerability at this level is the total time elements of the LAS were in range of enemy weapons.

At the next level down the decomposition of the two higher-level measures (rate of targeting and vulnerability), as mentioned above, is carried out and measures are applied to each aspect. The breakdown at this level is into procedural components and the measures of performance (MoP) are mostly times to complete each component (time to air, transit time, time to acquire, engagement time, re-tasking time). Such breakdowns are different for each set of procedures implemented and details for the different system configurations used in Prowling Pegasus will be reported elsewhere. However simple time measurements are not appropriate to the breakdown of vulnerability into the components as described above, and here a mix of quantitative measurement (numbers of threats known) and subjective assessment (degree of risk accepted) is required. A MoP for tactics might only be measurable in a comparison study and at the next higher level.[2] There are additional costs that need to be considered at this level which involve the human costs of the procedures (numbers involved, degree of skill/training required).

The MoPs of the components of the SoS are arguably at a lower level than those for procedural breakdown described above, although some technology insertions can very directly influence the MoEs without changing the high-level procedures. It is here that it becomes important to analyse the impact of both technology and procedural aspects on the MoEs and we have found it useful to describe such impact in the form of an influence matrix where eventually it will be necessary to quantify the elements of this matrix either by comparison experiments or subjective assessment by subject matter experts. However there is also the (desired) complication in such analysis when

[2] Aspects difficult to measure absolutely can usually be assessed in comparison studies where their effect is evident in the next higher-level measure.

procedures are modified to harness the potential of new technology insertion to produce overall system synergy and then the higher-level measure is the true guide to improvement. The SoS is decomposed into components and MoPs for these are devised. The details for the various SoS configurations used in Prowling Pegasus will be reported elsewhere, but in general the decomposition was into force mix components (helicopters, UAVs, HQ elements), C4ISR technologies (mission management system, Joint interoperability, situation awareness displays, information management architecture and communications technology) and integrated procedures (planning, reconnaissance cuing, 3rd party targeting). The impact of the procedural aspects at this level are also best observed at the higher levels. MoPs of the force mix elements generally relate to their impact at the higher levels (eg effectiveness of the helicopter for reconnaissance, effectiveness of a HQ element in reducing time to air) and for the C4ISR technologies MoPs are related to improved situation awareness and decision making, both of which are also higher level issues. Costs associated with the technology need to be assessed and factors involved include capital cost, training required and vulnerability (to attack or breakdown).

This analysis could be carried to further lower levels to examine the performance of the individual system components. To do this the components would need to be represented to sufficient fidelity to justify such detailed study. An area where this was attempted is in the information technology applied to situation awareness displays, mission management and information management. Some description of the concept demonstrator system that was constructed for Prowling Pegasus is given below. Detailed measurements of the parameters of these systems were carried out and will be reported in full elsewhere (ref 6) but a brief description is given below in section 7. A second area that was investigated in detail were the procedural aspects of the SoS, and again this will be described briefly below but reported fully elsewhere (ref 7).

benefit		**cost**
MoFE	Measure of achieving high level intent	Capital costs, force losses, civilian losses
MoE_1	Effectiveness of Land Air System	LAS related capital costs, force losses, civilian losses
MoE_2	Rate of targeting by LAS	LAS vulnerability
MoP_1	Times for procedural components	Human resource costs, risk accepted
MoP_2	Performance of system components	Capital costs, human resource costs
Dimensional Parameters	Low level data directly measurable from high fidelity representations	

Table 1. The hierarchy of metrics used for Prowling Pegasus.

4 The Land Air System Concept Demonstrator

The LAS had several configurations involving mixes of platform components including fixed wing strike aircraft (FA-18s), Armed Reconnaissance Helicopters (ARH), tactical unmanned aerial vehicles (TUAV), ground-based air defence (GBAD), forward air controllers (FAC), and several ground-based Land and Air HQ elements. The representation of these components in the SCD consisted of virtual platforms and representation in constructive simulations. Real people were used in key decision making roles, which included the pilots and crew of the ARH and fixed wing aircraft, ground based forward air-controllers (FAC), and a variety of roles in both Army and Air Force headquarters. Virtual cockpits for both rotary and fixed wing aircraft were used to allow the pilots to interact with the simulated battle and terrain of the constructive simulations described below. A summary description of these representations follows.

- Platform-based Mission simulators
  - ARH
    - Day and night out-the-window views
    - Target Acquisition and Designation System (TADS) including low fidelity NVG and FLIR type views, laser designation and ranging, and target selection and lock-on for weapons
    - EWSP: radar warning, missile warning, laser warning, audible and visual displays, and automatic dispensation of countermeasures
    - Moderate fidelity flight dynamics (6 degrees of freedom)
    - basic flight instruments including heads-up displays, multifunction stick, and pedals
    - Customised SA display with moving map, north or heading-up, blues and detected reds as either military symbols or icons, sensor fields-of-view, threat domes, flightplans, waypoints, no-go zones etc.
    - Weapons (Hellfires, rockets, guns)
  - Tactical UAVs
    - Simulated realtime sensor (TV, FLIR, NV) views for human operators can be provided in ground station, HQ or on board another virtual platform such as ARH
    - Interface for operator control of sensor look direction
    - Operator can laser range and designate from sensor view and handover target to any response asset
    - Can execute planned mission by waypoints or segments, or dwell on station, or by manual control by operator
    - Can add EW, comms and weapon payloads if required
  - Fixed wing aircraft (FA-18)
    - Out the window views
    - Moderate fidelity flight dynamics
    - Basic flight instrumentation

All the force mix components of the system were linked in the knowledge sphere by a technology concept demonstrator system, which enabled the application of NCW principles by allowing all players to have unrestricted sharing of situation awareness together with an ability to engage in collaborative planning and decision-making. This system, which we call LSAS (for land situation awareness system), uses a concept of information sharing, the ‘infospace’ described in reference 8, which allows all users on the system to access and deposit information in a distributed database. The human players in the experiment interact with this ‘infospace’ via a visualisation system, developed in-house using Autometrics’ “Edge Development Option”, which displays battlespace entities on a 3D terrain and allows computer aided route planning, threat assessment, reconnaissance planning and mission rehearsal with 3D ‘fly-throughs’. Instances of the LSAS were provided to all of the humans in the SCD and each was configured independently to suit the particular task. The pilots of the virtual helicopters for instance used their LSAS for navigation, display of mission profiles (as prepared pre-flight in the Aviation HQ), and situation awareness by displaying positions of friendly force elements and detected enemy (with associated ‘threat domes’ if identified). Connectivity of the ‘infospace’ in the real world is restricted by the communications technology available and our concept demonstrator uses simulation (ref 9) of the digital communications links including line-of-sight limitations (although this was not available in time for the experiment). Additionally, several voice communications channels were provided to allow this form of communication to augment the digital and assist in knowledge generation and sharing.

New procedures for the planning and conduct of the mission in the context of the NCW technology were developed through seminars involving military and system specialists, and these were further developed during the conduct of the Prowling Pegasus experiment. These procedures and the analysis of them are discussed further below but more fully in reference 7.

5 The Synthetic Environment

The SCD of the Land-Air BG interacted with constructive simulations of the rest of the friendly force and the enemy force. The ModSAF constructive simulation was used to represent the additional Land components and the STAGE simulation was used for additional Air elements. Detailed numerical models of radar surveillance assets were also included and the whole of the SE was linked using DIS protocols. Specialised interfaces between DIS and the ‘infospace’ were constructed (ref 10) to link the SCD into the SE. The information that was fed from the constructive simulations included the positions and status of all the blue elements and positions and status of the red elements as determined by the available surveillance assets. Where the surveillance assets were modelling in ModSAF, automatic feeds of the detections were fed into the ‘infospace’. For the virtual platforms, when a human detected and identified an entity through the view into the virtual world, this needed to be manually entered into the ‘infospace’ via the LSAS interface. The movements of blue entities in the constructive simulations were carried out by human operators (LOCON) who would receive commands from the HQ either by voice or via the LSAS, but usually a combination of both to facilitate the communication of intent. The red entities were controlled by another human player who represented an enemy commander (ENCON).

6 Experiment Construction

A scenario was developed which involved the LAS assisting a conventional mechanised Brigade in an operation of expelling an occupying force from a town (Katherine in Australia’s Northern Territory). The main task for the LAS was to find and destroy priority enemy targets outside the town.

The physical layout of the SCD was as follows. The Brigade HQ was sited in a tent in an open space at the DSTO site at Salisbury. This HQ was represented by a small staff of about five military, which carried out the command and support functions of immediate planning and airspace coordination. A similar number of scientific staff assisted the military in the operation of several LSAS terminals, which aided the military functions and provided the situation awareness as the scenarios were played out. The Brigade commander also had use of a large format 'Smartboard' which was linked to the LSAS. An Airforce element in the HQ operated the Air command support system, Phoenix, which was linked into the simulations and displayed the blue air entities and the red air entities detected by the radar models. All these air entities were also fed into the 'infospace' and could be displayed on LSAS terminals if required. One LSAS terminal in the HQ was configured to display both Air and Land entities together, representing a Joint situation awareness picture. Also in the HQ was the TUAV controller who had access to a virtual view from the constructive UAV in ModSAF. This operator was able to steer the sensor directions of the UAV and had access to a LSAS terminal when required to enter the locations and identifications of entities detected in the virtual view.

In a room nearby was the Aviation Regiment HQ, which carried out the ARH mission planning on an LSAS terminal. Also at the Salisbury site and located at separate locations were LOCON, ENCON, HICON and the two virtual ARH cockpits. ModSAF and the radar simulations were also sited at Salisbury and LSAS terminals were provided to most of the Salisbury locations. The virtual FA-18 cockpit, the STAGE wargame and a LSAS terminal were located at DSTO's Melbourne site. The Melbourne and Salisbury sites are 800km apart and were linked by landline, which carried the DIS traffic for the simulations, the simulated digital links of the 'infospace' and a simulation of the voice radio link between ground based Air HQ elements and the FAC to the FA-18.

The experiment was conducted over four days in March 2001. Day 1 was devoted to familiarising the military participants with the capabilities of the LSAS[3] and general briefing on the background to the missions. On subsequent days different configurations of the LAS were used in similar missions. Each mission lasted about 2 hours and was followed shortly afterwards by an after action review. The four configurations used were:

1. Two ARH's conducting search and destroy missions and networked to each other and the ground based HQs.
2. ARHs coordinating with: Special Forces conducting close reconnaissance and target designation; with GBAD for airspace control; and with a UAV for reconnaissance.
3. Fixed wing added, with the ARHs acting as forward air controllers
4. Same as previous, but with ARHs also carrying out an attack function.

7 Analysis

[3] A single day was insufficient to provide enough training to the military participants to make them proficient operators of the LSAS and auxiliary scientific staff that had received more extensive training provided the necessary skill level.

A feature of SE based experimentation is the ability to collect data. The complete sequence of events during a mission can be captured for later replay and analysis, but it is also possible for certain data to be processed and displayed to analysts in near real time. Missions could also be stopped and restarted to enable analysts to examine human factors issues, such as the state of situation awareness of participants or reasons for particular decisions, by direct questioning of the players. In Prowling Pegasus, several automatic data logging techniques were employed and these included:

- DIS logger, which logged all the data circulating on the network from the constructive and virtual simulations regarding entity positions and status;
- 'Infospace' record, which recorded all the information that was deposited in the 'infospace' ;
- voice traffic record;
- video of actions during the missions of the virtual cockpit and HQ functions.

Additionally, trained observers recorded the human processes that occurred with particular emphasis on the use of the LSAS, the HQ procedures and LOCON.

A key part of the analysis was the use of after action reviews (AARs), which gathered the opinions of subject matter experts on some of the human factors and TTP aspects of the system. The AARs were conducted shortly after the completion of each mission and an attempt was made to incorporate some results of first-cut analysis and replays of crucial segments of the missions using ModSAF and the LSAS. The intent was to stimulate the subject matter experts involved in the AAR to conduct their own analysis of the causes of decisions and actions that had significant effects on the course of the missions. However for a variety of technical reasons, this was unsuccessful. A further problem with the construct of the AARs was the that the higher level metrics had not been sufficiently defined prior to the experiment so that the questions were possibly not as relevant to these as could have been.

The data gathered is currently being processed to populate the various metrics discussed in section 3.

8 Results

The experiment provided examples of Land-Air battlegroups with intra BG coordination and synchronisation as well as external interactions facilitated by NCW technologies coupled with appropriately aligned procedures. Tasking, mission planning and mission conduct were performed collaboratively across the brigade and battlegroup using an advanced LSAS, which involved visualisation and planning tools with an underlying information management structure. Previous work (references 11 and 12) has provided strong qualitative evidence of the benefits of shared situation awareness. The current work has applied the concept specifically to the LAS with a concept demonstrator mission management system, and has attempted some quantitative measures of effectiveness.

The benefits of shared situation awareness were evident in the enabling of collaborative planning of the detailed ARH mission profiles, which impacted at the higher levels of MoEs of time to air (and hence target acquisition time) and reduced vulnerability. However, careful baselining experimentation would be required to quantify these impacts. We were able to gain some assessment of improvements as the participants learnt from one mission to the next how to better utilise the capability offered by the LSAS demonstrator.

The LSAS also impacted on the planning within the Brigade HQ by assisting the development of shared situation awareness. Again the impact of this is evident at the higher levels of measures of target acquisition rates and reduced vulnerability. How much the LSAS contributed to shared situation awareness is the subject of a separate investigation and some techniques for assessment of situation awareness were trailed in Prowling Pegasus (ref 6). An interesting contrast that emerged was the relative ease of generating shared situation awareness within the brigade HQ as compared with the difficulty of communicating the inherent understanding to the other HQ and LOCON, neither of whom were collocated with the Brigade HQ. This was despite all having the same information and the same visualisation available with the LSAS. It was readily apparent that direct personal interaction was a major factor in rapid development of shared situation awareness and this is to be further investigated. The shared situation awareness also had additional impact through the enabling of procedures for synchronisation of air-space and cooperative reconnaissance, target acquisition and engagement. Again the benefits were apparent at the higher level of measures (targeting rates, vulnerability, fratricide) and again the relative benefits of different aspects will require careful baselining and comparison experiments.

As alluded to above, the experiment gave only preliminary quantitative results on the benefits of NCW concepts to effectiveness of a LAS due to lack of a baseline measure and only partial development of appropriate procedures. The procedures that have been discussed, which were introduced to take advantage of the networking technology, could have been made even more effective if greater advantage of the potential of the LSAS had been appreciated and utilised by the military participants. A particular example was that little or no use was made by the FA-18 pilots of the potential offered by an LSAS system as enabled by digital information links. A combination of the short familiarisation period provided before the experiment and some 'unfriendly' aspects of the LSAS user interface (cluttered displays, clumsy information entry for ARH pilots, for example), had detrimental effects on user acceptance of the technology. Many advanced features of a LSAS which some participants identified during the experiment, have already been developed but, due to time pressures, were not used due to a technical problem of interfacing them to the SE. These problems will need to be remedied in future experiments.

A further problem with the validity of any quantitative measures was the design of the scenario. Although it had much military credibility it was not specifically designed to stress the issues relating to the effectiveness of the LAS and the NCW concepts. In particular, the enemy force was too inferior to the blue force so the use of the LAS did not have a decisive effect on the overall battle outcome. Thus any improvements to the overall mission effectiveness, due to the application of the NCW principles in a LAS, will not be readily apparent at the highest levels.

Other problems, related to the fidelities of representations of components of the SoS, also lower the validity of any quantitative results. Some examples are the inadequate representation of the UAV and its interface to the human operator, the cut-down representation of the HQ structure (with only token representation of the S2 cell for example), and the representations of the data communications links. The issue of the inadequate representation of the communications infrastructure (where all data links in the experiment were very high bandwidth) does have benefit in helping to define the bandwidth requirement to achieve the shared situation awareness necessary for the synchronisation and coordination procedures. The information passage in the LSAS system was designed to minimise bandwidth requirements in the expectation that the Land environment would be restrictive. The actual bandwidth required in the experiment will be extracted in the analysis of data collected and will serve as a guide to separate development of a communications infrastructure architecture to support the application of NCW concepts.

9 Conclusions

The major outcome from the Prowling Pegasus experiment has been the refinement of the LAS concept in the development of procedures to harness the potential of the NCW technologies employed. Many possible improvements to both technology and procedural aspects have been discovered and will be implemented in further iterations. However the quantitative measures obtained should not be used in any definitive way to argue the value of the particular LAS configurations due to the several inadequacies noted of this particular experiment. Analysis of the conduct of the experiment itself has affirmed the power of the methodology and most of the inadequacies have resulted from not adhering strictly to the stated methodology.

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