ENHANCEMENT OF A TAILORABLE DEFENCE ARCHITECTURE MODELLING TOOL

Brendan Kirby, Chris Martin, Angela Horseman and Yi Yue.

Land Operations Division,

Defence Science and Technology Organisation (DSTO)

PO Box 1500 Edinburgh, South Australia 5111, Australia

Phone: (618) 8259 6362, Fax: (618) 8259 5055

Email: brendan.kirby@dsto.defence.gov.au

8th ICCRTS

INFORMATION AGE TRANSFORMATION

June 17 – 19, 2003

National Defense University, Washington, DC.

Proposed Topic Area: C2 Assessment Tools & Metrics

ENHANCEMENT OF A TAILORABLE DEFENCE ARCHITECTURE MODELLING TOOL

Brendan Kirby[1], Chris Martin, Angela Horseman and Yi Yue

Land Operations Division, Defence Science and Technology Organisation,
P. O. Box 1500 Edinburgh, SA 5111, Australia
Email: brendan.kirby@dsto.defence.gov.au ph (618) 8259 6263 fax (618) 8259 5055

Abstract:
US DoD Architecture Framework (AF) products have been developed using Ptech's FrameWork for a Brigade HQ configuration for a hypothetical Modern Combat Force designed for 2016. These architecture products seeded the ideas of enhancing the design of an architecture tool to cater for a flexible force structure. An Australian Defence Enterprise Architecture (EA) tool has been tailored to associate information flows and activities with generic entities, to facilitate construction and analysis of an ORBAT for future design of an Objective Force. Needlines and information exchange requirements are automatically checked for consistency between force elements, and the activities are analysed as to whether their information exchanges match with input and output requirements. Warnings are produced if the output of a producing activity is not consistent with the input of a consuming activity. This flexible ORBAT structure enables entities to be added or deleted, and then to be tested whether the communications architecture can accommodate changes made and whether the information exchanges along needlines are consistent and suitably match with each other. Also, architectures can be created within another architecture, further augmenting the opportunity to pursue segmented analysis of the system, then as a whole.

1. INTRODUCTION

In Australia, the military has indicated that future requirements for deployable forces will need to have an intrinsically flexible force structure. Recently, battlegrouping has been discussed as an enabling concept that allows a case-by-case design of combined arms teams to achieve specific missions. Under this concept, the chain of command changes as units are re-grouped for different missions. Previously, networks followed the chain of command, now they would support the chain of command. This implies the requirement for high levels of interoperability between force elements to support a modular and flexible approach to force design. Therefore the concept of battlegrouping could be applied when task organising a force from the brigades of the Future Force down to the lowest level required.

In order to meet the wide variety of demands placed upon Australia's armed forces and the shorter time in which they are required to be operational, the structure of deployed forces will need to be flexible and adjustable. The Australian Army has documented a concept for Entry from the Air and Sea (EAS), which states that "an EAS capability provides a balanced, potent and flexible force structure for the range of supporting wider interest tasks" [1].

Chief Of Army Speech

In his recent address at the Land Warfare Conference (2002), the Chief of Army (CA) delineated certain requirements for the future of the Australian Army. His question: "How do we achieve the necessary flexibility, adaptability and agility within the force to be able to cope with these changing demands?" indicates a requirement for flexible and adaptable force structures [2]. The CA placed a

[1] Comments in this paper are the authors' opinions only, and are not officially endorsed by the DSTO or ADF.

premium on flexibility in assets and doctrine in a "come as you are" operation. The future force he was describing would be characterised by strategic agility, readiness and flexibility, focussed on littoral warfare.

The CA added emphasis to this direction by stating that the Australian Army would need to be "versatile, agile, scalable and adaptable". It would need to be deployable by air and sea (an EAS capability), interoperable with coalition partners, and prepared to take a leadership role in coalitions. The intellectual and doctrinal framework provided by manoeuvre operations in the littoral environment (MOLE) would be essential in the conduct of warfare in the future. (Hence the importance of the MOLE scenario discussed below.)

Therefore, it is clear that future Australian Land Operations require a technique and a tool that can provide assistance in designing flexible and adaptable force structures.

2. ENTERPRISE ARCHITECTURES

An architecture can contribute measurably to the roles of integration, interoperability, insertion of technology, cost reduction and organisation knowledge management. These contributions are made in three distinct manners in which an architecture is used, firstly, as a blueprint for the future, secondly as a current picture of the existing organization, and thirdly as a roadmap of guidelines on how to get there.

Architectures are an emerging approach for capturing complex knowledge about organisations and systems. Enterprise architectures are not only a mechanism for describing, managing and analysing complex organisations, but are also a means to ensure interoperability [3, 4] between various components within the architecture and across similar architectures.

Architectural approaches range from broad, enterprise focused applications, through to those aimed at specific user communities. Various US government organisations are employing EAs, namely Treasury, Commerce, DoD, DOE and the Environmental Protection Authority (EPA). The EPA has designed, implemented and recently updated its EA. With its different layers, the EA provides a strategic framework and knowledge base to help make decisions on how information technology can work. It helps provide the strategic knowledge base that is critical to furthering the mission of the EPA [5].

EA is an organizational blueprint that depicts how an agency's various IT and management elements work together as a whole. It shows the current environment and a targeted environment—and provides a road map for getting to the targeted environment. EAs inherently require constant examination and updating [6]. The US Office of Management and Budget (OMB) has stated to agency managers that an EA is essential in order to receive funding. The OMB has indicated that real budget decisions will be based on analysis using the EA of the organisation [6].

With the recent advent of architecture methodologies, EA tools and Architecture Frameworks (including the US DoD AF); the inception, development and usage of architectures to manage the complexity of diverse organisational structures is only increasing. Therefore, the application of EAs to describe the deployable force structure and function, and to provide analysis options for differing configurations is being pursued. This will provide a mechanism that can quickly support and assist in the design of a Future Force and to provide advice and feedback to the operational commander.

The Australian Defence Architecture Framework

Within the defence community, the US DoD AF [7] is emerging as one method for capturing the knowledge of how a defence force can be organised for particular missions. The Australian Defence Organisation (ADO) has mandated the use of the Defence Architecture Framework (DAF) to design the defence information environment. The DAF has been designed to be interoperable with allies, and levers off the US DoD AF, but is also augmented by the META Group Enterprise Architecture Strategy. The architecture products presented in this paper are consistent with the requirements of the DAF, but more importantly, derive from one knowledgebase rather than from disparate sources or different tools.

Context of the MOLE architecture model

The recent Australian Defence White Paper [8] focuses on the stability, integrity and cohesion of our immediate neighborhood as one of Australia's key strategic objectives. Since all of our neighbors are island and archipelagic states, a MOLE capability is essential to our future land force to support regional security. MOLE requires integrated sea-land-air operations within the littoral environment spanning northern Australia out to the inner arc [9, 10]. Figure 1 displays the 'High Level Operational Concept Graphic' for this scenario.

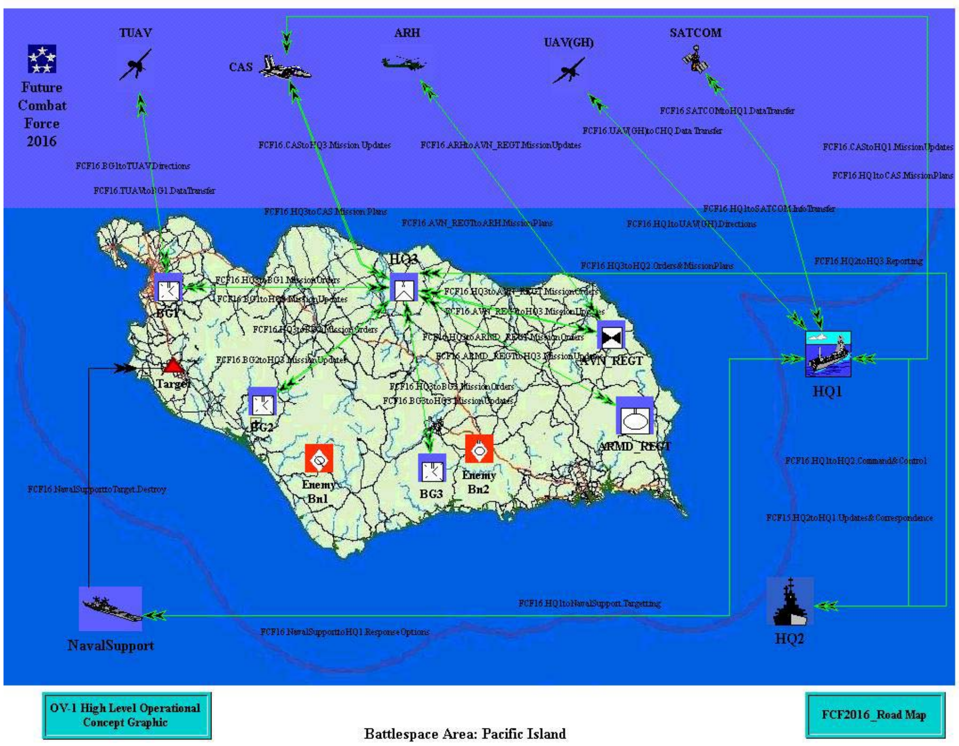


Figure 1. OV-1 High Level Operational Concept Graphic

The context for the Operational View (OV) above is that a hypothetical island in the South West Pacific has been invaded by another country. Australia is leading a coalition operation to restore territorial integrity and re-establish sovereignty of the local people on the island. The operational concepts employed are based on the Army's current vision of future C2 with an emphasis on mission command (through dissemination of the commander's intent), synchronisation of action achieved through appropriate doctrine and shared Situation Awareness (SA), and responsive targetting via an integrated network of sensors, actors and controllers [9].

3. A STATIC ARCHITECTURE DESCRIPTION

A particular future land force structure was applied to the MOLE scenario discussed above. An architecture was developed to illustrate the efficacy of this force structure in satisfying the requirements imposed upon it by the scenario. An EA tool designed by Ptech, called FrameWork was utilised to produce a number of the essential products under the direction of the US DoD AF. The Operational Node Connectivity (OV-2) and the Command Relationships chart (OV-4) that were constructed are shown in figures 2 and 3, respectively, illustrating the application of a future land force structure to a MOLE concept of operations [9]. These Operational Architecture view products are descriptions of the organisation and its roles and behaviours as it might be in 2016. The EA produced provides a blueprint of the deployed force structure, and can be used to provide operational commanders information regarding future force structure and information exchange requirements and flows between various entities and HQs. It is very important for the commander to have access to an overall description of his

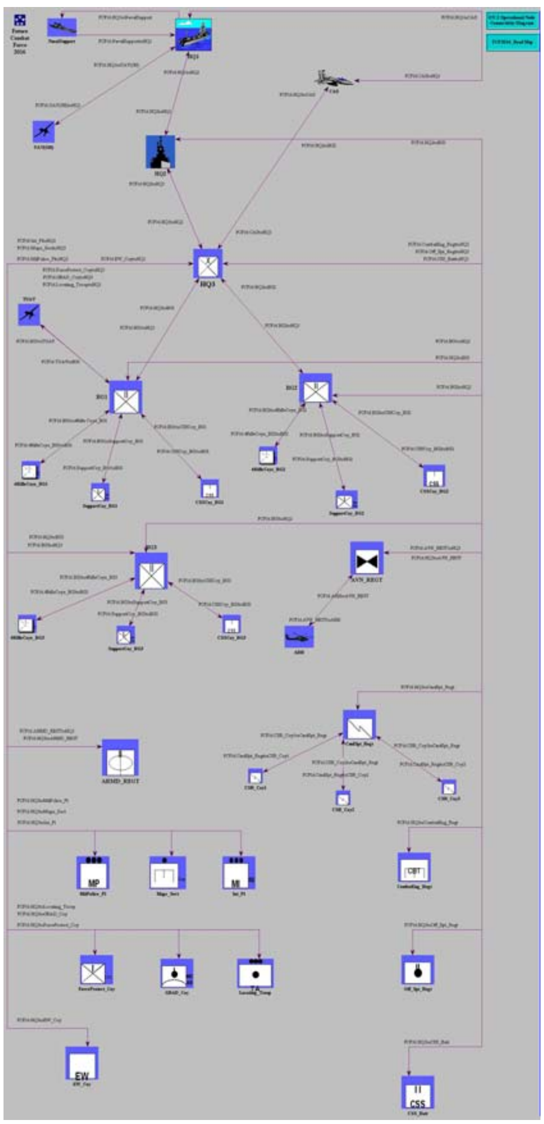


Figure 2. OV-2 Operational Node Connectivity Description for the Future Combat Force

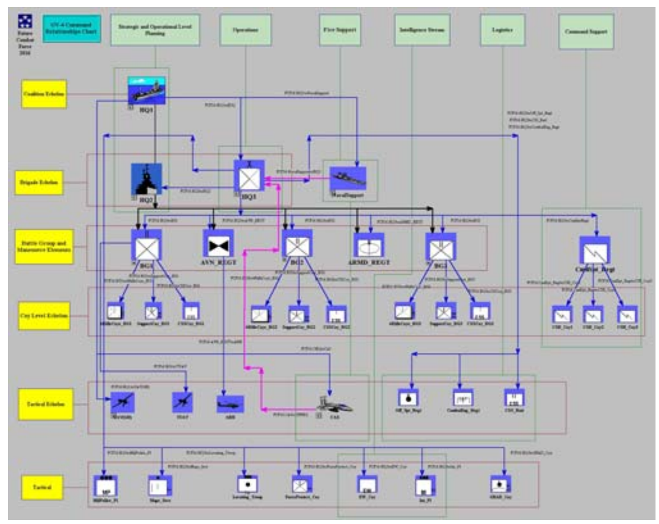


Figure 3. OV-4 Command Relationships Chart

military organisation, and from his experience base, to make recommendations and changes as required. A number of other Operational and System view products were also developed for this organisation, and are included in the Appendix.

Nevertheless, the architecture produced within FrameWork is a static description, and is not executable. An executable simulation based on different architecture configurations can be quite informative in gaining insight into communications bottlenecks, optimised C2 structure, and other operational parameters. Previously, an executable simulation of two architectures produced in CORE, demonstrated clearly the superior functionality of one configuration above another [11, 12]. Here, in this case, it can be seen that the architecture is not flexible, and is quite fixed in its representation of the underlying knowledgebase.

The need for a flexible architecture tool

Concomitant with the need for an architecture description of the military organisation, is the requirement to assist commanders in the modern context of dynamic and turbulent pressures to design future deployable forces within short time frames for a variety of contingencies. Capability development and long term planning are also important factors. Consequently, a tool is required which can cater for rapid changes in force structure (such as the deletion or addition of force elements) and then to automatically indicate to the commander whether these changes are technically viable. If an ARH troop for example, was required to be moved from an aviation battlegroup to support an infantry group, would the communications between nodes be compatible, and if so, would the information exchange requirements for the extra functionality be met? In pursuit of these goals, a flexible architecture tool has been customised to give the commander insight into force design, long term planning and capability development.

4. PRIOR DEVELOPMENT OF THE ADF CONCEPT ARCHITECTURE TOOL (CAT)

The CAT is a product that initially was specifically developed for the ADF by Information Networks Division (IND), DSTO (under contract to Codarra Advanced Systems) to conduct communications analysis. Later the Defence Information Environment Architecture Office (DIEAO) extended its capability to support architecture development, analysis and planning within the ADO. The ADO owns the intellectual property, which is a big advantage when requiring an architecture modelling tool so that in-house changes can be made. Other commercially available EA tools did not provide an application programming interface to enable customisation of the tool.

Features of the CAT

The CAT functions through a Web browser interface to an SQL-compliant database, it is a distributed application, and hosts a single database for the (potentially) whole Defence enterprise – so that multiple users can add to and complement the total architectural structure. The CAT categorises reusable items covering the full range from low-level elements such as interface descriptions, to components such as radios and computers, to high level systems such as complete aircraft with all included systems. The CAT can also capture information flows and activities such as a Warning Order, for example [13 – 15].

The motivation for the development of an Australian Defence architecture tool has stemmed from a number of sources. These include the need for a greater understanding and delineation of various aspects of the military system such as:

- C2-related processes,
- Information exchanges within and between entities,
- Current and future C4 capabilities,
- Identifying and prioritising C4ISR shortfalls,
- Joint applications,
- Defence related databases, and
- Development and retention of corporate knowledge [13, 15].

Complex defence architecture development efforts require the support of sophisticated enterprise architecture tools. An alternative to existing architecture tools is the development of a custom tool, specifically to satisfy the needs of ADF architecture developers. The Concept Architecture Tool supports C4 capability analysis and planning activities. Under contract to the Defence Information Environment Architecture Office (DIEAO), Codarra has developed the tool into a robust general purpose architecture tool with the intent of supporting architecture development and visualisation [14, 16].

5. DETAILS AND STRUCTURE OF THE CAT

The CAT database contains an open-ended hierarchical taxonomy of military entities. An entity recorded in the database may be either specific (it may actually exist) or generic (it doesn't exist *per se* but describes a type or class of entity). In effect, generic entities act as templates for the creation of specific entities. For example, the CAT may contain information about a specific entity called "ARH1" being a specific instance of the generic entity "Armed Reconnaissance Helicopter". Armed Reconnaissance Helicopter may in turn be recorded as an instance (or more appropriately, *sub-type*) of a more generic "Aviation Sub-unit" entity. In object-oriented design terms, ARH1 *is-a* Armed Reconnaissance Helicopter which in turn *is-a* Aviation Sub-unit.

A present limitation of the CAT is that an entity cannot be recorded as belonging to two or more types. The taxonomy is strictly hierarchical. The purpose of the taxonomy is simply to classify entities. The hierarchical taxonomy is not to be confused with a command hierarchy. The CAT records information about specific entities and their generic types, but not about where those entities may sit in a particular ORBAT.

Our Contributions

The early development work for the CAT was carried out by IND, the DIEAO and Codarra. We have added functionality to suit our more specific purposes in designing a flexible architecture tool. The CAT database contains information about military activities in which entities may engage. An activity may be associated with many different entities, and an entity may be associated with any number of activities. Therefore, when a new specific entity is created, it now inherits the activities associated at that moment with the generic entity from which it was created. The user may then adjust the list of associated activities to suit the specific entity's role. A limitation of the present version is that each activity may take at most one input and produce at most one output. Inputs and outputs are quite arbitrary; they could be signals, reports, plans, talcs, orders or other items. However, in the CAT, an activity cannot output both a report and an order, for example.

Information exchanges (called "InfoFlows" in the CAT database) tie together paired entities and activities. A contrast is drawn between "specific" information exchanges that link specific entities, and "generic" information exchanges that link generic entities. A generic information exchange elucidates the fact that an entity of type *X*, when engaged in activity *A*, needs to exchange information with some other entity of type *Y* engaging in activity *B*. In each information exchange at present, one entity is known as the "information producer" while the other is the "information consumer". Whenever a specific entity is placed into a scenario, the CAT will automatically scan the other entities already in that scenario and use generic information exchanges as templates to create new specific information exchanges between the entities based on their associated activities. (The present version of the CAT will identify applicable generic information exchanges based only on a specific entity's immediate generic type. It will not recurse up the taxonomy to match against super-types of the specific entity.)

Generic information exchanges also allow the CAT to check that all entities in an OV2 have their information needs satisfied. For every pair of unlinked entities (without a needline), the CAT will display a highlighted link if there is a generic information exchange covering entities of the same generic types engaged in the same activities. Also, if a specific entity's type and activities match a generic information exchange that requires the entity to exchange information with some other type of entity that does not exist in the OV2, a broken highlighted link will be displayed hanging off the entity. The user may select this broken link to view the generic information exchange in question and thus identify the type of entity missing and its matching activity.

Using the CAT: A Flexible Architecture Tool

The CAT creates generic entities and generic information flows within the CAT Explorer. A scenario is then created with the Scenario Builder, and these entities are copied into the scenario. From the scenario an architecture is then created, where the entities required are selected.

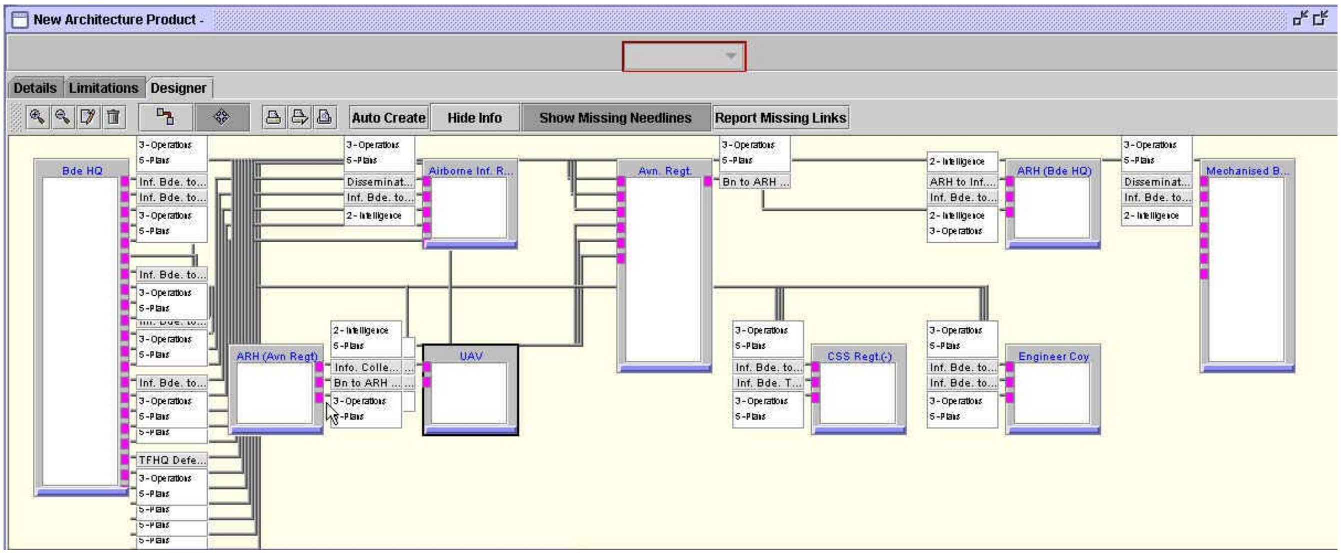


Figure 4 Designer view of the automatic creation of the OV-2 from within an Architecture created from a particular scenario

The architecture products, consistent with the US DoD AF can then be automatically created in rudimentary format by the CAT. Figure 4 shows an OV-2 automatically created within an architecture created from a particular scenario. The adaptability and flexibility of the CAT is exemplified in Figure 5 where missing information flows between entities selected for the architecture are highlighted. This is achieved by selecting the “Show Missing Needlines” button. A “Report Missing Links” function has also been designed to elucidate communication disconnects. A dialogue box illustrating this is shown in Figure 6.

6. APPLICATIONS OF THE CAT

Nesting of Entities

Entities can also be assigned to other entities [17]. If an entity has C4 components or systems, and is assigned to another entity, then the entity it is assigned to will “inherit” the C4 components and systems. This nesting feature of the CAT may have applications for future analysis of military formations.

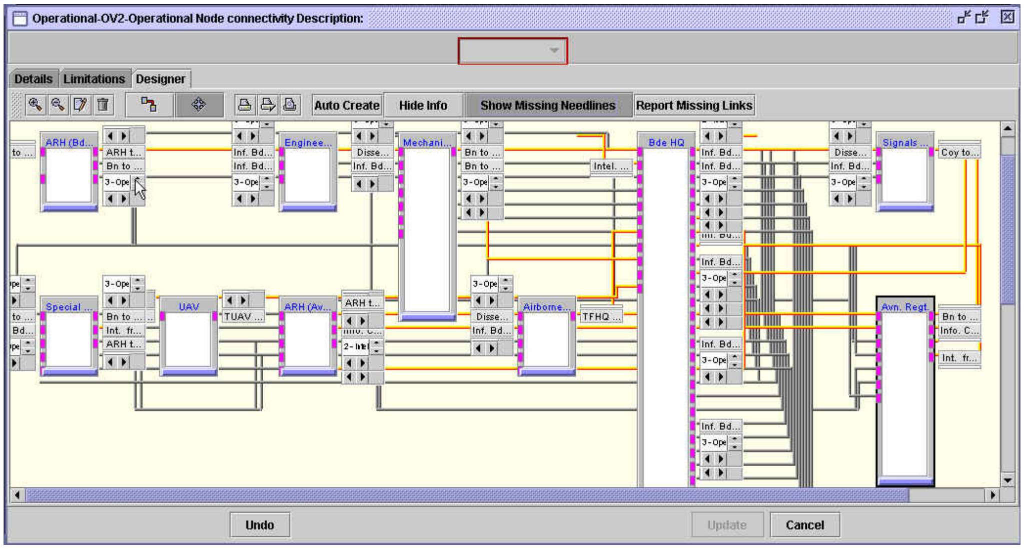


Figure 5 The "Show Missing Needlines" functionality is invoked and the light coloured lines indicate which information flows are currently not possible in this architecture design.

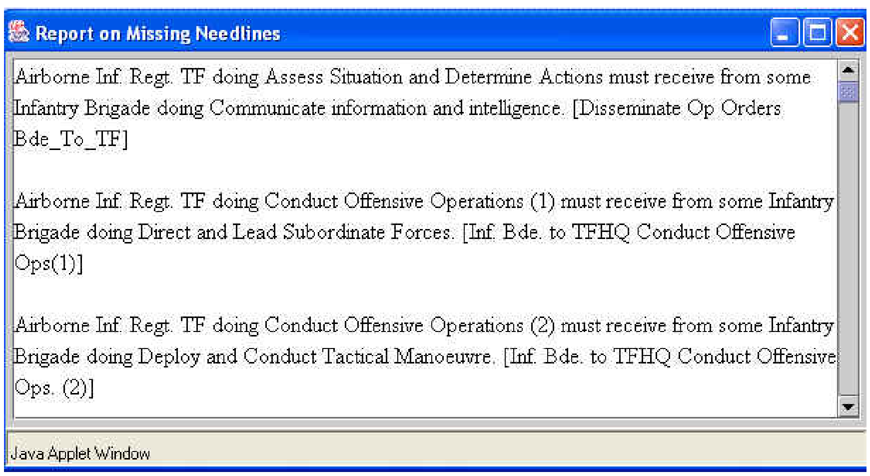


Figure 6 The "Report Missing Links" function has also been designed to elucidate communication disconnects.

Nesting Architectures within Architectures

Another exciting application is the creation of architectures within an architecture. For example, it is possible to create a Commander with a number of subordinate staff. All of the required information flows can be created, within a scenario, including the means for communication and the interfaces that exist, between the staff and the Commander. An architecture can then be developed using those staff, the Commander and the associated information flows.

The Commander and staff can then be allocated to a company, which is an entity in its own right. The company represents a previously developed and tested architecture, consisting of the personnel nested within it. At this stage of development, the information flows will not be automatically copied into the company, but the information flows can be represented by links between the personnel. Figure 7 is the Designer image of the assignment of personnel to a basic company architecture.

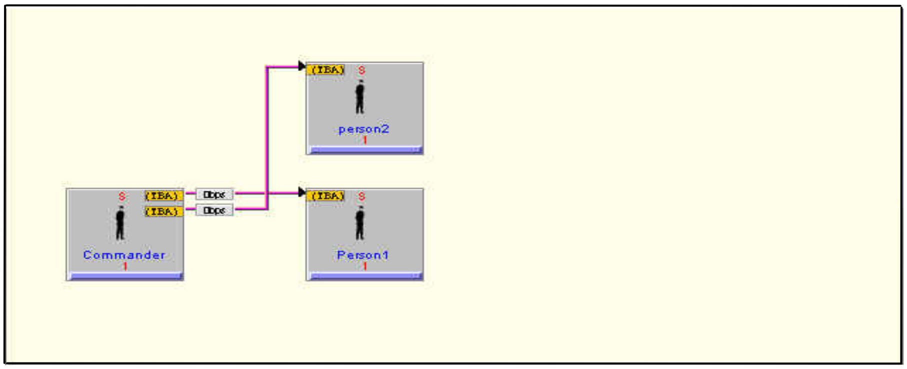


Figure 7 The Commander and his staff, nested within the architecture for a Company

Tests Of Communication Lines

An entity can be allocated C4 components or systems that have been previously built in the CAT. This makes it possible to select a communication interface for that entity [17], and provides the ability to test the compatibility of the interface between the source entity and the destination entity of an information flow. A failure in the test would indicate that the communication devices are not adequate for the required exchange of information and further consideration of communication requirements may be necessary. It is this feature of the CAT that allows the user to identify some of the shortfalls in the design of the C4ISR architecture.

Hence, the communication lines between individual persons within a military unit, whether it is a Company, Battalion or Brigade Headquarters can be tested. Modifications can be made to the formation of the unit and the C4 components and systems within the scenario as is necessary to obtain a robust architecture. Once this testing is complete, and the appropriate C4 devices have been allocated and necessary information flows are satisfied between personnel, the bigger picture can then be developed.

The bigger picture using the example above would be the inclusion of the Company in a much larger Architecture, such as an ORBAT for a brigade. The validity of the smaller architecture does not affect the validity of the larger architecture. For example, if person 1 and person 2 belonging to a Company have a missing information flow between them, this does not affect the Company's ability to exchange information with Brigade Headquarters.

The CAT has the capacity to perform an analysis of small military units, and the flexibility to make appropriate changes to the structure of the units to ensure they can carry out their functions and roles. It is then possible to construct multiple, larger military formations or architectures by including the previously examined military units in different combinations. These can then be analysed, and missing information flows and C4ISR shortfalls of the formations can be detected and corrected.

This potential capability of the CAT has not been fully explored as yet, and it should be noted that further experimentation is required to test the robustness of the system.

7. DISCUSSION

Importance Of EA Development

The US DoD next year will start integrating a common set of information services over the Global Information Grid. Scheduled for completion later this decade, the grid will be a globally connected, single information system with an EA called the Net-Centric Enterprise Service (NCES). The NCES will offer a common set of information capabilities over the grid to access, collect, process, store, disseminate and manage information. Therefore, the DoD is anticipating this EA to facilitate faster decision cycles by providing information in an optimum format and timely manner to meet operational, tactical and mission support needs [18]. In Australia, the awareness of the importance of the development of a comprehensive EA from a common database for the ADF to facilitate long term planning, flexible force design and reuse, and capability development is increasing.

Visualisation of EA

An EA visualization tool can graphically display the linkage between the strategic plan, the mission and the business processes of the organisation. Going from the serial text documents to graphically depicted architectures has made it easier for the operative to absorb required information. The National Oceanic and Atmospheric Administration are employing an EA visualization tool using XML to provide four different views of the department's architecture – business process, information, applications and technology infrastructure. This EA visualization tool can graphically depict the relationships among these elements [6]. Therefore, using a graphically rich visualization format will make it easier to engage stakeholders with the significance of the enterprise architecture process.

Solving Complex Problems

Many organisations are developing EAs in order to address and solve a variety of complex problems. Problem domains ranging from air traffic management [19] to business processes [20] are each being tackled with architecture methodologies. Utilising an executable architecture, Wagenhals *et al.* have carried out logical, behavioural and performance analyses of a representative architecture [21]. As a mechanism for analysing complex systems, executable architectures are still in their infancy, but the promise of behavioural and performance analyses of a military system against chosen metrics is a strong enticement for further development in this area. For example, the provision of operational updates (and indirectly, the generation of situation awareness) via information exchanges within certain time intervals could be tested for a particular architecture with an executable model.

The division of Information Sciences at the Argonne National Labs has developed a modelling and simulation approach called the Dynamic Information Architecture System (DIAS) to address complex adaptive problems. The DIAS is an object-oriented framework which chooses one or more disparate information systems, models or simulations to dynamically interoperate in the same frame of reference to solve the unique problem at hand, and can be used to model and analyse an architecture [22].

Social Network Analysis

Another approach to analysing organisations, which focuses primarily on a network-based view of the relationships between people and groups is Social Network Analysis. Social Network Analysis is a mechanism for analysing and comparing formal and informal information flows in an organisation. It can be used as well to correlate information flows with the organisation's work processes. Social Network Analysis aims to visualise relationships between people using diagrams, to study the factors that influence relationships (eg. age, background, training), and to draw out bottlenecks where multiple information flows funnel through one person or section (or where information flows do not match with the formal group structure) [23]. The most important goal for Social Network analysis is to make recommendations to improve communication and workflow in an organisation. Dekker has applied Social Network Analysis to C4ISR architectures by employing a FINC method, which calculates a number of simple metrics for comparing and quantifying organisational network aspects of C4ISR architectures [23]. He concluded that the FINC method provides a way of evaluating the efficiency of organisational structures for military organisations, particularly in relation to the flexible structures required when military forces carry out non-traditional activities [23, 24]. This might prove to be another technique that can be employed to optimise the formation of flexible force architectures.

8. CONCLUSION

Architecture products have been produced for the ADF using a commercial EA tool. Standard commercial EA tools were found to be static and inflexible. The customisation of the ADF Concept Architecture Tool has been carried out, and its preliminary capability as a flexible architecture tool has been received enthusiastically by the military, which will assist in providing a more flexible design capability in creating and analysing an Order of Battle. A panorama of applications of EAs is taking place. EAs are becoming a standard mechanism for understanding, managing and analysing complex systems and organisations.

9. REFERENCES:

[1] *Army Development Concept for Entry from Air and Sea*; SO2 Concepts, Future Land Warfare, Canberra, Australia.

[2] Chief of Army Speech, "*Future Wars – Futuristic Forces*", Land Warfare Conference, 22-24 October 2002, Brisbane Convention & Exhibition Centre, Australia.

[3] Bob Seymour, Brendan Kirby, Jeremy Krieg, Darryn Reid and Mark Unewisse, "*Achieving Interoperability through an Information Management Architecture*", Proc. 5th International Command and Control Research and Technology Symposium, Canberra, Australia, October 24-26, 2000.

[4] Darryn Reid and Wayne Johnson, "*A System Design Archetype for C4ISR systems of the 21st century"*, Proc. 7th International Command and Control Research and Technology Symposium, Quebec City, Quebec, September 16-20, 2002.

[5] Wilson Dizard, *EPA forges an enterprise architecture,* GCN news, 7 Oct 02, Vol. 21 No. 30 http://www.gcn.com/21_30/departments/20150-1.html

[6] Richard Walker, *Get down to business with an architecture,* GCN news, 7 Apr 03, Vol. 22 No. 7, http://www.gcn.com/22_7/enterprise-architecture/21535-1.html

[7] DoD Architecture Framework Working Group, *DoD Architecture Framework Version 2.1* (2000).

[8] Commonwealth of Australia, *Defence 2000: Our Future Defence Force*, pp. 30-31, 2000.

[9] Yi Yue, Brendan Kirby and Bob Seymour, "*Developing an operational architecture for the Australian Army enhanced combat force in the digitised network-centric battlespace*", Proceedings of SPIE Vol. 4396, Battlespace Digitisation and Network Centric Warfare, Orlando, USA, April 18-20, 2001.

[10] Future Land Warfare Branch (Army Headquarters), The Australian Army, *Concept for Manoeuvre Operations in the Littoral Environment*, 2000.

[11] Brendan Kirby, Leong Yen, Greg Judd and David Cropley, "*Optimising the Design of Land Force C2 Architectures"*, Proc. Command and Control Research and Technology Symposium, Monterey, California, June 11-13, 2002.

[12] Brendan Kirby, and David Cropley, "*Modelling and Simulation of Military System Architectures Using CORE*" Proc. International Conference of Systems Engineering, Los Angeles, California, July 29 – 31st 2002.

[13] Nico Padovan, "*C4 Analysis Tool, The CAT*", presentation to DSTO (2001).

[14] Paul Prekop, Gina Kingston, Moira Chin and Anna McCarthy, "*A Review of Architecture Tools for the Australian Defence Force*", DSTO Tech Rep 1139 (2001).

[15] Marcel Scholz, Ian Grivell, Matthew Britton and Meredith Hue, "*A Review of Communication Network Architecture Development Tools*", DSTO Tech Rep 1258 (2002).

[16] *C4 Analysis Tool (CAT),* Stage 3 Prototype User Manual Version 3.h. Draft, 21 Nov 2000. Codarra Advanced Systems; *The Mature ADF C4 Analysis Tool (CAT),* Statement of Requirements, Version 1.0, October 2000.
[17] Concept Architecture Tool (CAT), *Stage 4 Concept Demonstrator User Manual Version 4-1-3,* Codarra Advanced Systems, Canberra, Aust. (Nov 2002).
[18] Dawn Onley, *DOD lays out enterprise architecture plans*, GCN news, 4 Apr 03, Vol. 22 No. 7, http://www.gcn.com/vol1_no1/enterprise-architecture/21630-1.html
[19] Agam Sinha, Frank Willingham and Michael Hermes, *An Architecture Framework for Decision Support Systems (DSSs) in Air Traffic Management*, Syst Eng **4** (2001) 1–12.
[20] F. P. M. Biemans, M. M. Lankhorst, W. B. Teeuw and R. G. van de Wetering, *Dealing with the Complexity of Business Systems Architecting*, Syst Eng **4 (**2001) 118–133.
[21] Lee W. Wagenhals, Insub Shin, Daesik Kim and Alexander H. Levis, *C4ISR Architectures II: A Structured Analysis Approach for Architecture Design*, Syst Eng **3** (2000) 248-287.
[22] Peter Campbell and John Hummel, "*The Dynamic Information Architecture System: An Advanced Simulation Framework for Military and Civilian Applications*" http://www.dis.anl.gov/DIAS/papers.htm
[23] Anthony Dekker, *Applying Social Network Analysis Concepts to Military C4ISR Architectures* Connections 24(3): 93 – 103 (2002).
[24] Anthony Dekker, *C4ISR Architectures, Social Network Analysis and the FINC Methodology: An Experiment in Military Organizational Structure* DSTO General Document 0313 (2002).

APPENDIX:
A basic overview will be given of some of the AF products and of the concept of an architecture, prior to the presentation of various OV and SV products.

A Defence Enterprise Architecture consists of different views of the operation, business or system being described. Collectively the views define the design, structure and behaviour of the operation, business or system. The DAF describes these views within four categories – Common, Operational, System and Technical. Some views are essential to the composition of an architecture, while other views are supporting and back-up the essential views.

The purpose of an Enterprise Architecture is to uniformly define the subject operation, business or system to support analysis and decision-making. Every architecture must contain a common subset of products. This common set of products is called, collectively, the Essential products or views. These constitute the minimal set of products required to develop architecture descriptions that can be commonly understood and compared.

The essential products are intended to describe and define the underlying operation, business or system, suitable for presentation to decision-makers. Because decision-makers need to compare multiple architecture products against each other, these products must contain similar information. For example, an Operational Node Connectivity Description (OV-2) in an architecture must be readily comparable to an OV-2 in another architecture. It is not the intent that these essential products will form the sole basis for decisions; rather they are intended as decision-support products.

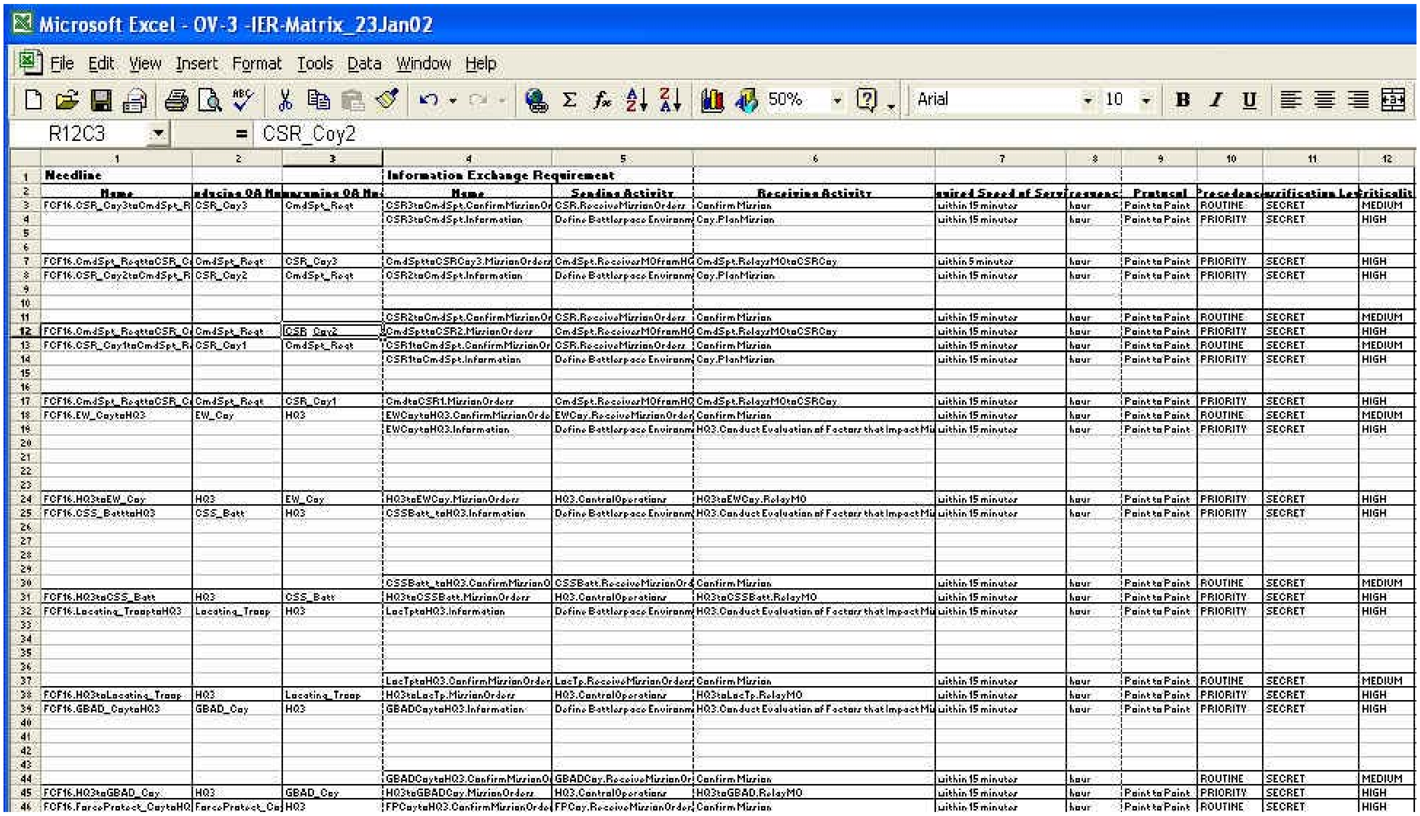
Operational Node Connectivity Description (Background on Figure 2 in main text)
An OV-2 is a diagram showing the information exchanges required between operational nodes and allows a viewer of the product to determine what connections are necessary to satisfy the defined business needs. An operational node can represent a role (eg Commander Australian Theatre), an organisation (eg Defence Materiel Organisation) or a facility (eg Australian Theatre Joint Intelligence Centre or a Field Hospital).

Information exchange characteristics are shown as a summary on the diagram (in Ptech they are devolved into an array of forms), and more comprehensively in matrix format in the Operational Information Exchange Matrix (OV-3) shown in figure A1, below.

The needline arrows do not indicate how the information transfer is implemented. The implementation (what systems are used to effect the transfer) is shown in the Systems Interface Description (SV-1); the communications pathways (eg via Local Area Net, multiple hops between source node and ultimate destination node) are shown in the Systems Communications Description (SV-2).

Activity Model (shown below in Figures A2 – A4)
Activity Models are hierarchical in nature; i.e. they begin with a single box that represents the overall activity and proceed successively to decompose the activity to the level required for the purpose of the architecture. Detailed activity models are sometimes needed for analysis and discovery of issues, but only the higher levels, or abstractions of the higher levels, should be provided to decision-makers.

Activity Models describe the business processes associated with the architecture, as well as the relationships and dependencies amongst the business processes, information exchanged between business processes, and external interchanges.



	1	2	3	4	5	6	7	8	9	10	11	12
1	Needline			Information Exchange Requirement								
2	Name	oducing OA No	nsuming OA No	Name	Sending Activity	Receiving Activity	quired Speed of Servi	requenc	Protocol	Precedence	ssification Le	riticalit
3	FCF16.CSR_Coy3toCmdSpt_R	CSR_Coy3	CmdSpt_Regt	CSR3toCmdSpt.ConfirmMissionOr	CSR.ReceiveMissionOrders	Confirm Mission	within 15 minutes	hour	Point to Point	ROUTINE	SECRET	MEDIUM
4				CSR3toCmdSpt.Information	Define Battlespace Environm	Coy.PlanMission	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
5												
6												
7	FCF16.CmdSpt_RegttoCSR_C	CmdSpt_Regt	CSR_Coy3	CmdSpttoCSRCoy3.MissionOrders	CmdSpt.ReceivesMOfromHQ	CmdSpt.RelaysMOtoCSRCoy	within 5 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
8	FCF16.CSR_Coy2toCmdSpt_R	CSR_Coy2	CmdSpt_Regt	CSR2toCmdSpt.Information	Define Battlespace Environm	Coy.PlanMission	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
9												
10												
11				CSR2toCmdSpt.ConfirmMissionOr	CSR.ReceiveMissionOrders	Confirm Mission	within 15 minutes	hour	Point to Point	ROUTINE	SECRET	MEDIUM
12	FCF16.CmdSpt_RegttoCSR_C	CmdSpt_Regt	CSR_Coy2	CmdSpttoCSR2.MissionOrders	CmdSpt.ReceivesMOfromHQ	CmdSpt.RelaysMOtoCSRCoy	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
13	FCF16.CSR_Coy1toCmdSpt_R	CSR_Coy1	CmdSpt_Regt	CSR1toCmdSpt.ConfirmMissionOr	CSR.ReceiveMissionOrders	Confirm Mission	within 15 minutes	hour	Point to Point	ROUTINE	SECRET	MEDIUM
14				CSR1toCmdSpt.Information	Define Battlespace Environm	Coy.PlanMission	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
15												
16												
17	FCF16.CmdSpt_RegttoCSR_C	CmdSpt_Regt	CSR_Coy1	CmdtoCSR1.MissionOrders	CmdSpt.ReceivesMOfromHQ	CmdSpt.RelaysMOtoCSRCoy	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
18	FCF16.EW_CoytoHQ3	EW_Coy	HQ3	EWCoytoHQ3.ConfirmMissionOrde	EWCoy.ReceiveMissionOrder	Confirm Mission	within 15 minutes	hour	Point to Point	ROUTINE	SECRET	MEDIUM
19				EWCoytoHQ3.Information	Define Battlespace Environm	HQ3.Conduct Evaluation of Factors that Impact Mi	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
20												
21												
22												
23												
24	FCF16.HQ3toEW_Coy	HQ3	EW_Coy	HQ3toEWCoy.MissionOrders	HQ3.ControlOperations	HQ3toEWCoy.RelayMO	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
25	FCF16.CSS_BatttoHQ3	CSS_Batt	HQ3	CSSBatt_toHQ3.Information	Define Battlespace Environm	HQ3.Conduct Evaluation of Factors that Impact Mi	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
26												
27												
28												
29												
30				CSSBatt_toHQ3.ConfirmMissionO	CSSBatt.ReceiveMissionOrd	Confirm Mission	within 15 minutes	hour	Point to Point	ROUTINE	SECRET	MEDIUM
31	FCF16.HQ3toCSS_Batt	HQ3	CSS_Batt	HQ3toCSSBatt.MissionOrders	HQ3.ControlOperations	HQ3toCSSBatt.RelayMO	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
32	FCF16.Locating_TrooptoHQ3	Locating_Troop	HQ3	LocTptoHQ3.Information	Define Battlespace Environm	HQ3.Conduct Evaluation of Factors that Impact Mi	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
33												
34												
35												
36												
37				LocTptoHQ3.ConfirmMissionOrder	LocTp.ReceiveMissionOrders	Confirm Mission	within 15 minutes	hour	Point to Point	ROUTINE	SECRET	MEDIUM
38	FCF16.HQ3toLocating_Troop	HQ3	Locating_Troop	HQ3toLocTp.MissionOrders	HQ3.ControlOperations	HQ3toLocTp.RelayMO	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
39	FCF16.GBAD_CoytoHQ3	GBAD_Coy	HQ3	GBADCoytoHQ3.Information	Define Battlespace Environm	HQ3.Conduct Evaluation of Factors that Impact Mi	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
40												
41												
42												
43												
44				GBADCoytoHQ3.ConfirmMissionOr	GBADCoy.ReceiveMissionOr	Confirm Mission	within 15 minutes	hour		ROUTINE	SECRET	MEDIUM
45	FCF16.HQ3toGBAD_Coy	HQ3	GBAD_Coy	HQ3toGBADCoy.MissionOrders	HQ3.ControlOperations	HQ3toGBAD.RelayMO	within 15 minutes	hour	Point to Point	PRIORITY	SECRET	HIGH
46	FCF16.ForceProtect_CoytoHQ	ForceProtect_Co	HQ3	FPCoytoHQ3.ConfirmMissionOrde	FPCoy.ReceiveMissionOrder	Confirm Mission	within 15 minutes	hour	Point to Point	ROUTINE	SECRET	HIGH

Figure A1 Example of an OV-3 The Information Exchange Matrix

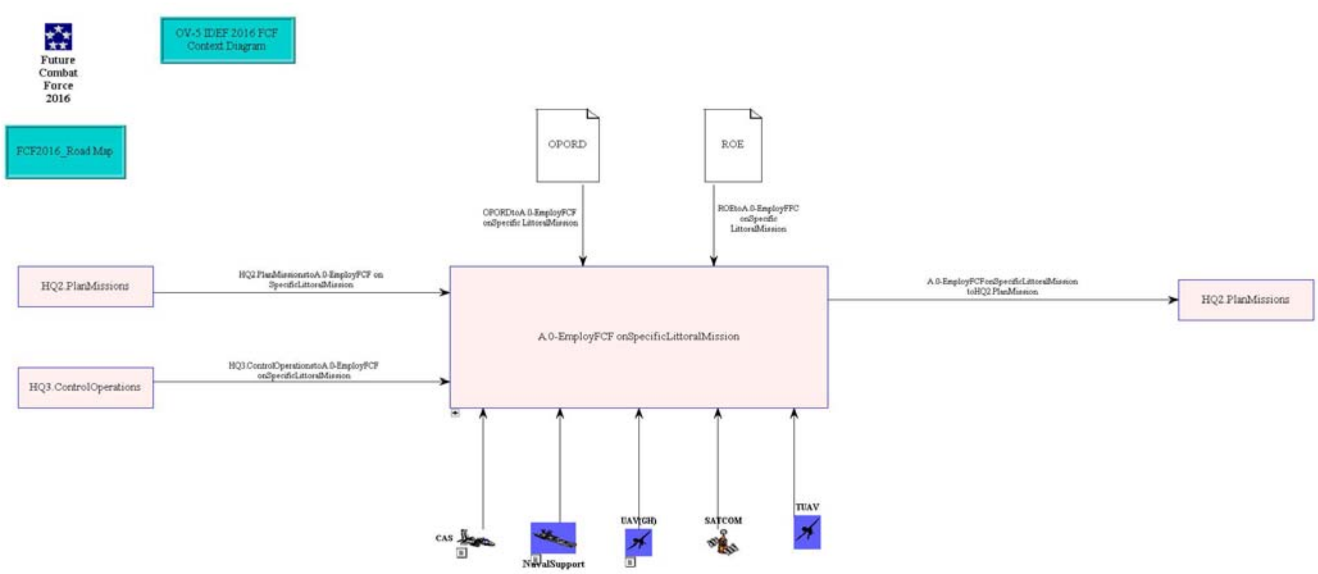


Figure A2 Example of an OV-5 Context Diagram

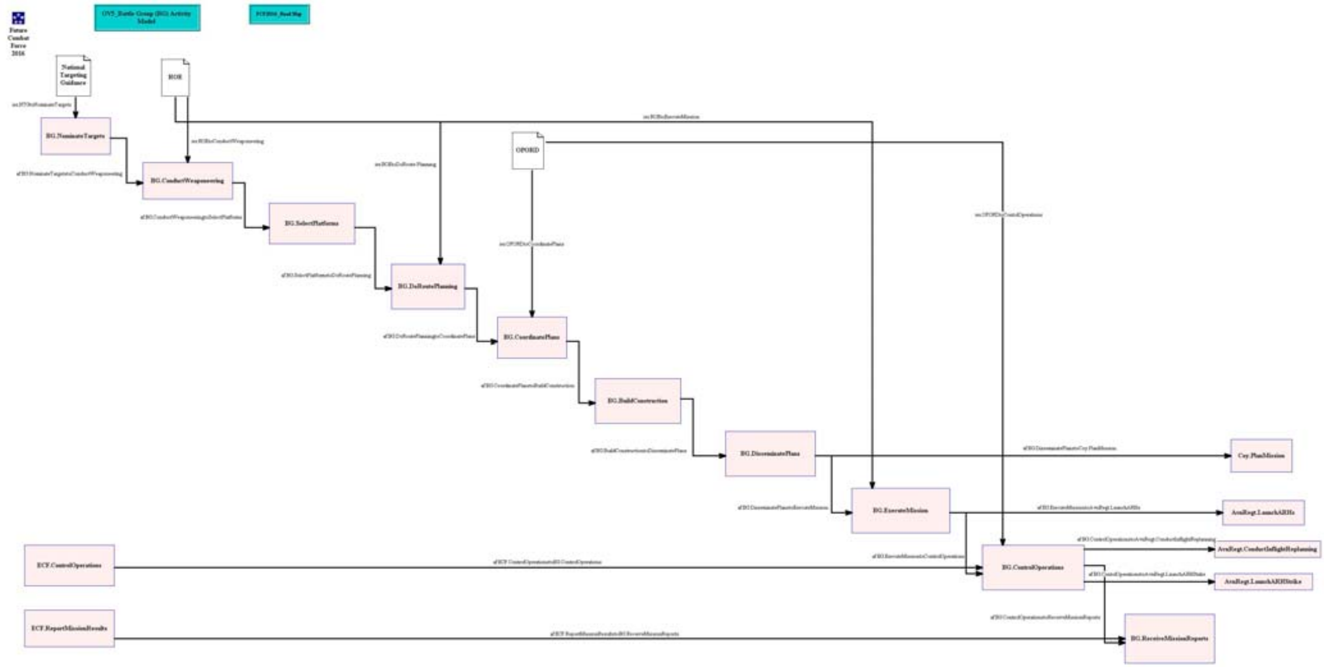


Figure A3 Example of OV-5 Activity Model for a Battlegroup

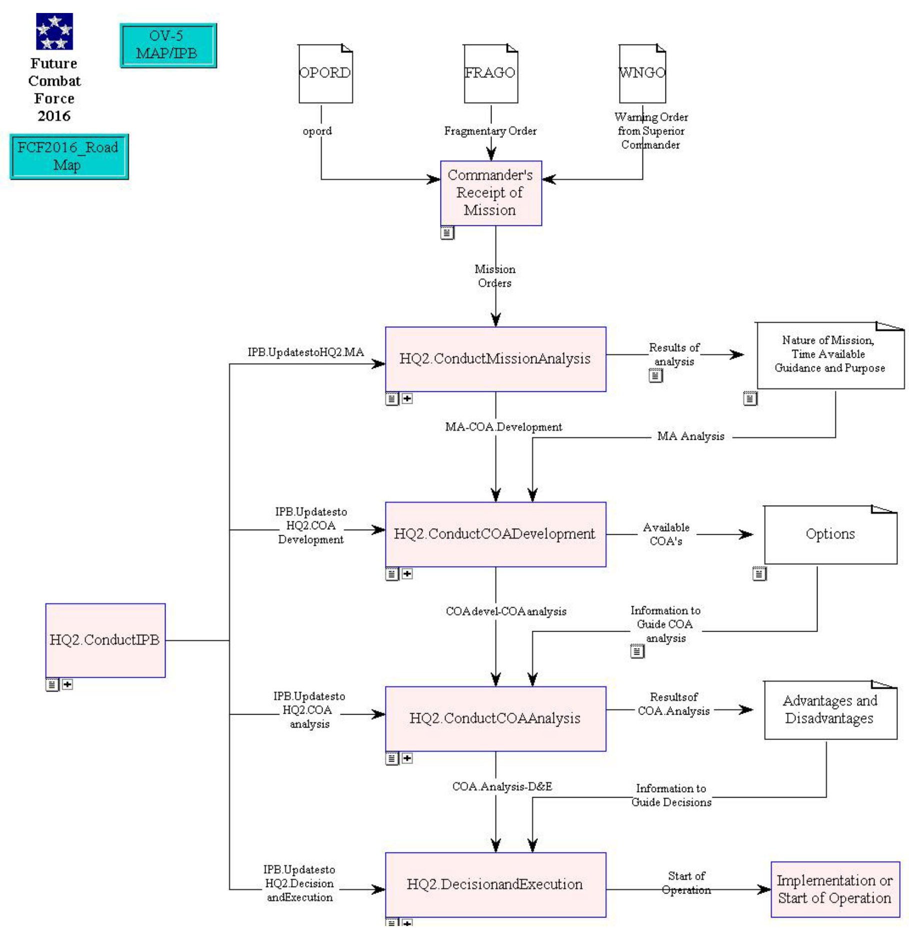


Figure A4 OV-5Activity Model for the Australian Military Appreciation Process

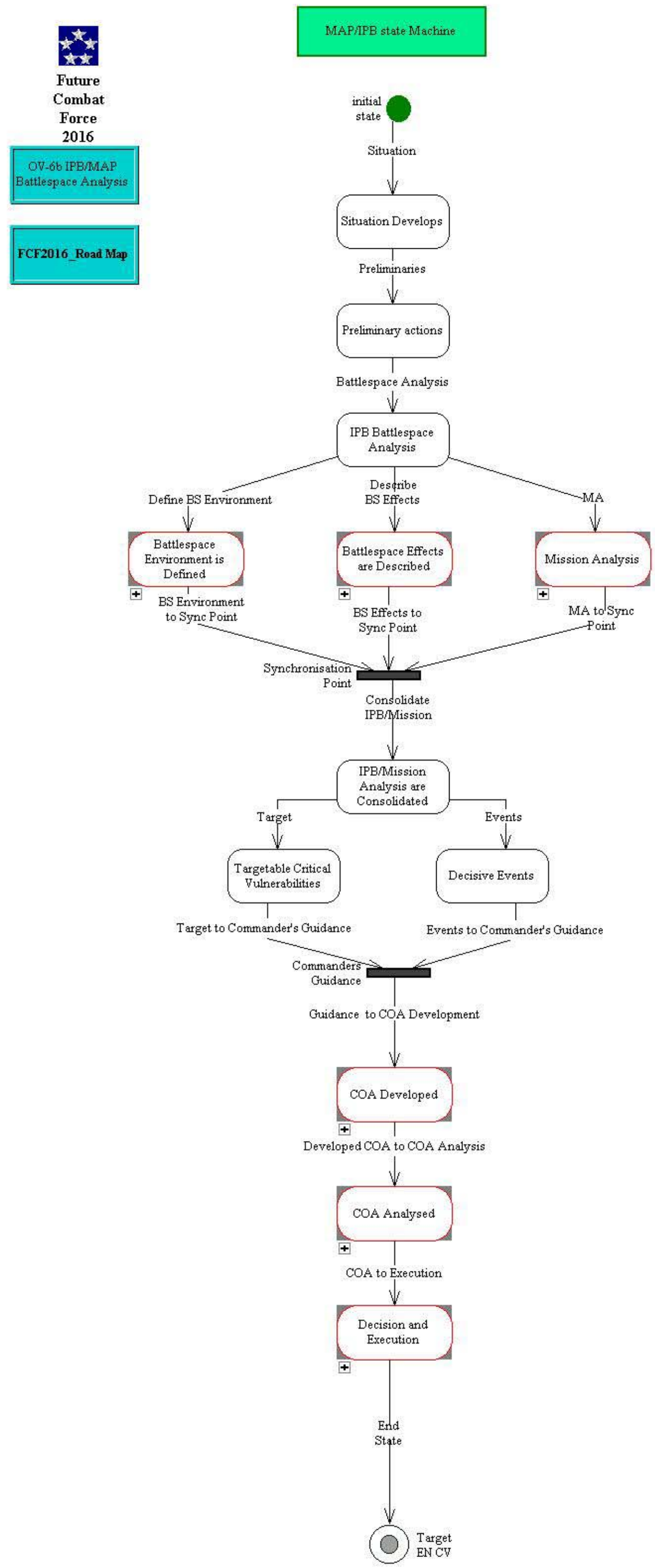


Figure A5: OV-6b Operational State Chart for Battlespace Analysis

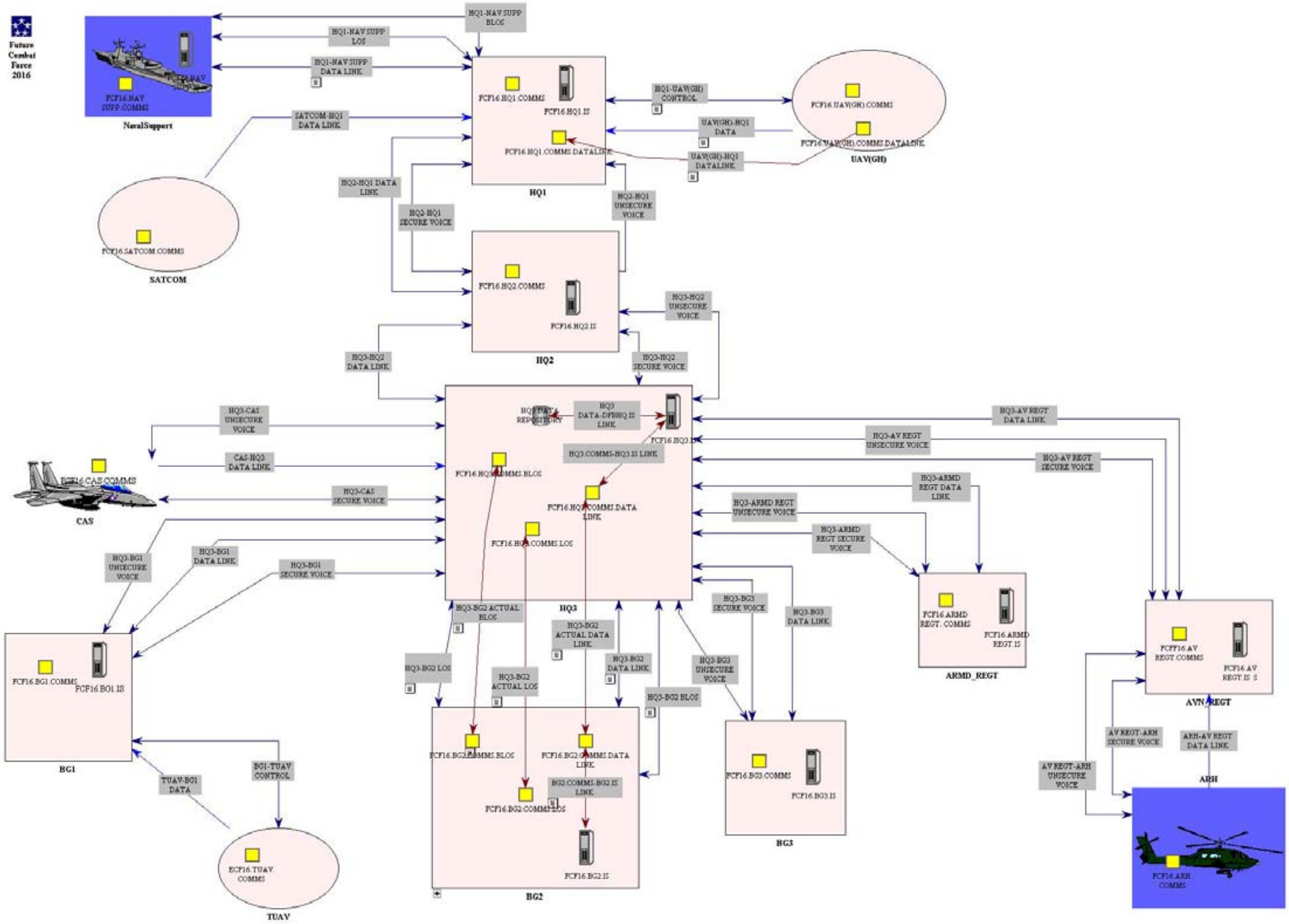


Figure A6: SV-1 System Interface Description

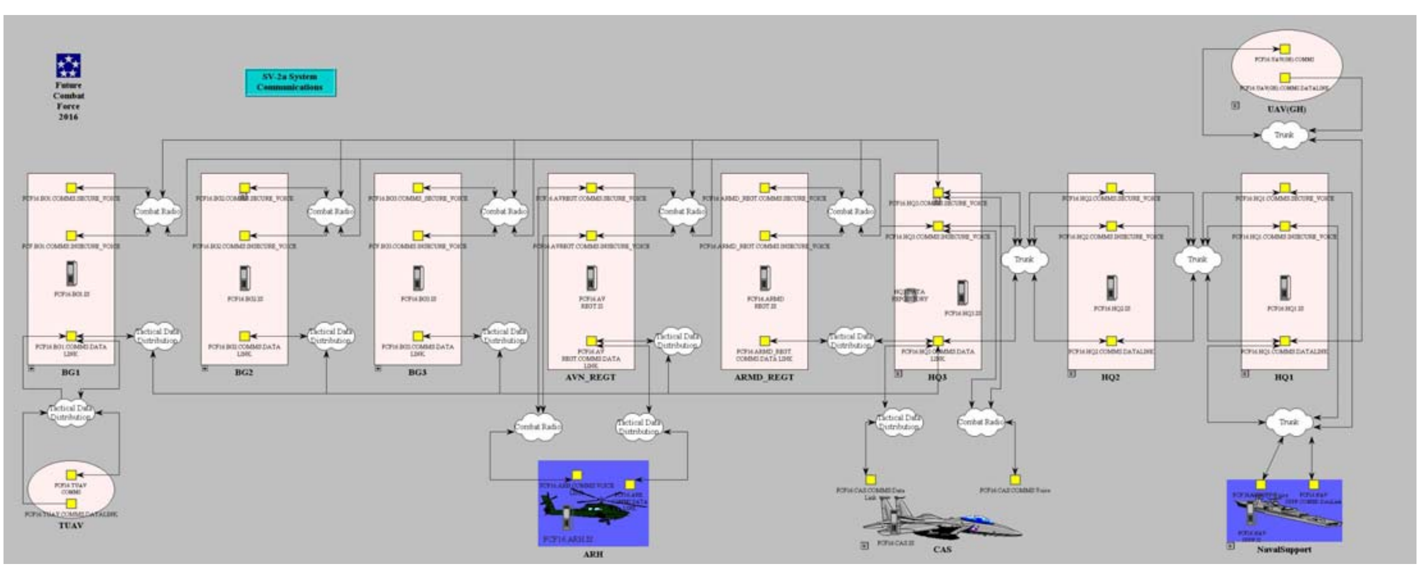


Figure A7: SV-2 System Communications