EXPERIMENTATION OF COMPLEX ADAPTIVE AEROSPACE MISSION CAPABILITIES

Research Questionnaire

Sub-problem 1 V1.0

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INTRODUCTION

This questionnaire is designed to investigate a sub-problem for RAAF sponsored research with the University of South Australia and a NATO Research & Technology Organisation (RTO) Technical Activity. A copy of the Research Plan of 30 May 2008 containing further details of the background to the research, it's key themes and all the references cited is available separately.

The contemporary conventional wisdom is that on the battlefields and battlespaces of the near future our soldiers, sailors and airmen will be presented with ever increasing voluminous and often conflicting data from multiple network capable systems and sources and will face 'cognition overload'. Experimentation and test and evaluation (T&E) in general are major activities during the development and ultimately the validation and verification of such systems during the capability acquisition process to ascertain their operational suitability and effectiveness. Surprisingly, there is still no accepted international standard for T&E or experimentation for today's military systems let alone tomorrows network enabled, complex, adaptive ones. The references in the Research Plan highlight that various NATO studies, such as the Air Launch Weapons Integration ALWI-2 (2004), have identified the need to address this situation. While many NATO nations test and operate aircraft using various standards for subsystems, the requirement to conduct experimentation and flight test validation of joint aerospace capabilities in a network enabled integrated mission environment will need to become an essential part of the scientific and engineering skillsets of NATO nations. The techniques required to develop, experiment, test and certify ever increasingly complex, safety critical systems and/or capabilities will involve unique skills and experience which have not yet been widely available amongst most NATO nations. Previous research documented Hayes and Alberts Experimentation Code of Best Practice (CoBP) (2002), NATO RTO C2 Assessment CoBP (2002) and the more recently published 'The Technical Cooperation Program's (TTCP) Guide to Experimentation or GUIDEx (2006), MIL-HDBK-1763 (1998), the US Joint Mission Environment Test Capability (JMETC) initiative and the Joint T&E Methods (JTEM) approaches where such tailorable frameworks will be used as a starting point.

As the first step to a NATO Standardisation Agreement (STANAG) and even an ISO standard for networked enabled T&E and experimentation, a CoBP drawn from national approaches covering modelling and simulation (M&S), and ground / flight test is proposed to address this deficiency. The NATO RTO Systems Concepts and Integration (SCI) Panel have been conducting research into the Validation & Validation of Network enabled capabilities under SCI 189 and have agreed in principle to the proposed research for development of a CoBP by their Flight Test Technology Team (FT3). Currently it is proposed that the CoBP will be published as an AGARDOgraph with participation by all of the key members nations titled "**Joint Aerospace Integrated Mission Environment for Experimentation CoBP"**. The CoBP is expected to be similar in nature of that completed by NATO RTO for C2 Assessment under SCI Research Group SAS 026 and published under the US Command & Control Research Program (CCRP). The NATO RTO M&S Group, International T&E Association (ITEA), Society of Flight Test Engineers (SFTE) and the Flight Test Society of Australia (FTSA) have also agreed in principle to seek their members voluntary participation to help the national representatives involved with the research and formal approval of the CoBP. The National Test Pilot School in Mojave, California are also participating to ensure that the experimental methods and frameworks are appropriate to the next generation of modelling & simulation as well as ground and flight testing.

The fundamental problem this research will seek to answer is:

> ***To what degree can experimentation be utilised to enhance the confidence in our network-enabled complex, adaptive, aerospace mission capabilities?***

Overall, the sub-problems used to explore this question with you and other Australian and international subject matter experts are:

- **Sub-problem 1 –** What is the utility of the contemporary capability development and management models that are in use? (This document, with responses due in December 2009)

- **Sub-Problem 2** – What is the suitability of contemporary systems engineering, interoperability and experimentation practices for current and future complex, adaptive military aerospace mission system capabilities intending to be network enabled and used with air armament? (Responses are currently scheduled for June 2010)

- **Sub-Problem 3 –** Is a code of best practice that incorporates modelling and simulation into experimentation, modelling & simulation and ground and flight T&E frameworks achievable now that will enhance the confidence in the operational utility of current and future network enabled, complex adaptive aerospace mission systems? (Responses are currently due in early 2011)

- **Sub-Problem 4 –** Determine insight from case studies of the application of this code of best practice and model to real world avionic mission system upgrades and network enabled operational experimentation.

Each Sub-question is explored in individual questionnaires with Sub-problem 4 being addressed separately using differing research techniques as described in the Research Plan. Responses may be made via hardcopy using fax, on-line, in the Word version or via personal interviews.

ETHICS STATEMENT

Please note that this questionnaire is unclassified and has been drawn from **unclassified, open sources** and are those of the author. They are intended to promote awareness and discussion on the challenges being faced to improve the experimentation of Australia joint forces, major allies and coalition partners as we transition to network-enabled 'tailored effects' based defence forces.

Collection of data is entirely for this purpose as indicated in the cited Research Plan. The data will not be used for any other purposes, nor will data be provided to others in a form that will enable identification of the respondent.

Further details of University of South Australia's ethics criteria may be found at:

http://www.unisa.edu.au/policies/policies/alpha.asp#res

(Original Signed)

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BACKGROUND TO COMPLEX ADAPTIVE SYSTEMS

While there is no universally agreed definition for a ***complex system***, the term is usually applied to systems with 'many strongly-coupled degrees of freedom', Wikipedia (2007) and are today generally seen as 'a collection of autonomous elements that interact both with each other & with their environment and that exhibit aggregate, ensemble and macro-behaviours that none of the elements exhibit", Alberts & Hayes (2007). The term 'system' is, however, highly overused, with it being casually applied to everything from a Home Entertainment System, to the affairs of government of a nation (System of Government) and to the planets orbiting the Sun (Solar System). Added to the mix is the use of adjectives for 'systems' such as 'simple', 'complicated'[1] (presumably those that aren't 'simple') and 'complex'[2] often without a definition or description of what is meant. Truly *complex systems* are fundamentally different to complicated systems. Complicated systems (such as aircraft, ships and vehicles) may usually today be reduced to their parts for both design and analysis purposes so that their behaviour and even any emergent properties can be predicted to a high degree of certainty and confidence. Complexity Science[3] is the emerging field potentially providing some better insights into the fundamental principles and theory for complex engineered systems and their patterns of behaviour frequently using anti-reductionist ways of thinking. It is suggested by Dr Terry Moon of DSTO that the salient features of systems displaying complex behaviours include:

- Interactions that are non-linear and include feedback loops.
- They are open systems where there is a net flow of flux (energy, matter or information) across the system boundaries; although specific boundaries may be difficult to determine and depend on the perspective of the observer.
- There can be nesting where component systems are themselves complex systems. The component systems may be connected so as to a form small-world network with a multiplicity of connections.
- Complex systems display emergent phenomena[4] and have 'memory' in the sense that prior states influence present states (formally they are said to exhibit hysteresis).

Complex adaptive systems (CAS) are special cases of complex systems that are designed to have the capacity to change and 'learn' from experience. Today they are often a form of systems containing many autonomous agents who self-organize in a coevolutionary way to optimise their separate values. Complex systems often use networks that may be seen as being configured for an overall purpose. They would, ideally, be designed to provide versatility, robustness and potential for growth (ie scalable[5]) rather than optimised for narrow functionality. The research will address the experimentation of aerospace mission systems[6] in the joint aerospace environment – which does

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1 Used to describe an intricate system with many components that each perform specific, usually highly specialised, functions and are designed for operation as part of a larger system: they are not intended to operate as separate, autonomous systems.

2 One not describable by a single rule. Structure exists on many scales whose characteristics are not reducible to only one level of description. Systems that exhibit unexpected features not contained within their specification. Systems with multiple objectives. See http://www.calresco.org/glossary.htm as of 21 Aug 2007.

3 The study of the rules governing emergence, the constraints affecting self-organisation and general system dynamics in nonlinear adaptive interacting systems. The study of the collective behaviour of macroscopic collections of interacting units that are endowed with the potential to evolve in time.

4 Those behaviours, features or functionalities that pertain to the network in its totality and cannot be attributed to individual elements. They may be patterns of behaviour, structural features or functionalities arising from the connection of the elements into a network and the subsequent interaction of those elements. Peer-to-peer networking on the Internet is an example of such an emergent phenomenon.

5 The property of a system or network which indicates its propensity to be readily enlarged, physically or functionally. The term is used in telecommunications and software engineering to indicate whether a system's performance can be increased in proportion to the capacity added.

6 Which includes: the air or space vehicles' Data Management System, Navigation, Communication, data links, ground control station, electronic surveillance and warfare systems such as Radar, Electro-Optic / Infra-red, Acoustics, EW Self-Protection, etc **and** (obviously) the Armament/Ordnance Stores Management / Fire Control Systems.

mean interfacing and cooperating[7] with land and maritime environments.

RULES OF ENGAGEMENT FOR THE JAIME CoBP

- As a NATO CoBP for JAIME Experimentation is proposed as one tangible outcome of the research (see Sub-Problem 3) there will need to be formal member nation ratification of the AGARDograph considered as part of the research plan. The NATO CoBP AGARDograph will cover:
    - Joint network enabled, effects based, aerospace weapon systems
    - the four domains of warfare: physical, information, cognitive, social
    - complex adaptive systems including:
        - sensors
        - command and control as well a promoting the cooperation and collaboration transition
        - force application and air armament as well as directed energy
    - defence experimentation, including all forms of the T&E alphabet soup
    - modelling and simulation
    - ground and flight testing
- The candidate proposes to use the successful Joint Ordnance Commanders Group for Aircraft Stores Compatibility approach for consensus based standards to do so. Inputs from academia, industry and defence will be widely sought, collated and used for analyses, review and approval by the national NATO SCI FT3 representatives prior to use of the NATO RTO AGARDOgraph review and publication processes. The implication of this is that any inputs to the CoBP specifically will obviously need to have your national representatives support.
- Responses to the research questionnaire can also be made shortly on the University of SA's website at www unisa.edu.au using Maven99 as the password. You can also request a personal interview, or email any comments directly to me courtesy of malcolm.tutty@defence.gov.au / TUTMG001@student.unisa.edu.au or fax them to 61 (0)8839 32819.
- Your national representatives at the time of writing are as follows:
    - AS: WGCDR M.G. Tutty with Dr T Moon, DSTO as SMEs
    - CA: TBA
    - FR: TBA
    - GE: TBA
    - IT: TBA
    - US: W. Lowry with USAF: FLTLT S. Bird AFSEO, USN: Mr A. Piranian & USA: M. Johnson as Service SMEs
    - UK: Mr D. Morley with dstl and Service SMEs TBD
    - NATO M&S Research Group POC: TBD
    - NATO MSA Air Armament Panel/Working Group POC: Mr A Piranian
    - US DOD CCRP POC: TBD
    - Contact details are available from the candidate upon request.

[7] The idea that two agents can increase both their fitnesses by mutual help rather than by competition. This assumes that resources adequate for both exist, or are created by the interaction, and relates to synergy and 'compositional evolution'.

RESEARCH SUBPROBLEM:

What is the utility of the contemporary capability development and management models that are in use?

What is your experience with the outcomes of the capability development and/or management processes?

Are you fully conversant with Operational Concept Document, Function & Performance Specs, Equipment Acquisition Strategies for major and minor capital equipment acquisitions? If so what are examples you have been personally involved with?

How did those projects go, and why?

To aid you in the completion of this questionnaire before you think about the 'producing system' lets first think about what are the future capabilities that are important to your frame of reference that would be influenced by capability development and the management models – the product? What products apart from planes, ships and tanks need to be factored into future capability management from your perspective?

Do you think a defence capability model that builds on technology readiness levels, systems engineering, and test and evaluation to give operational staff more confidence in the operational utility of network enabled aerospace mission systems intended for use with air armament is actually possible at all?

What is your experience and understanding of simple, complicated and complex systems integration and/or acquisition?

Is a capability development model applicable to complex adaptive systems also possible by any acquisition system in your view?

Are you familiar with the CD and CM process of any other nation? If so, who's specifically?

What do you understand the reference model and process to be for each nation and what are the references?

Why is it different to models used by other nations – since such processes are all intended to procure what is often the same defence material?

Are you familiar with the ADFs Mortimer Review of the Defence Material Organisation or any national review of acquisition in your country. If so, did the Review get it right and what needs to be done and why? If not, are any reviews underway for capability management processes that you're aware of?

Why is it seemingly so difficult to develop a streamlined acquisition process? Feel free to comment on Defence's ability in any country to adequately reflect on any systemic reasons for a projects success and meaningful feedback on experience.

What is your mind model of how it should all work from lust to achievement of the Initial Operational Capability at least?

What needs to be done – think macro and micro not just for minor and major acquisitions but also for simple, complicated and complex systems ...

Are you aware of any major changes to any of the nation approaches being implemented/proposed that you're aware of? What do you consider the relevance to the research may be?

Please discuss any related research into "Capability Management" that you are aware such as Les Vencels PhD work or Eric Honours on the worth of Systems Engineering with Uni SA, especially any international approaches being taken – such as RTO SCI 168 for example.

Please identify any other capabilities or major issues with the extant Operational Concept Documents due to network enabling initiatives not covered by current ADF programs:

Please review what you consider to have been the maturity and/or health of OCD/OR/Conops relative to the FPS/EAS etc you were using. (Was the OCD and FPS derived from previous successful programs of similar size and complexity or were they written to meet deadlines and there were serious cost and schedule differences between CDG and DMO and hence the contractors expectations!)

What were the contributing factors to the major cost or schedule implications of this – both positive and negative.

What should be done to rectify this maturity issue, if it has been an issue for you?

Is there any difference between indigenous or overseas ‘COTS/MOTS’ systems in your experience? If so, why, citing actual examples?

The following books are strongly recommended as background reading for network enabling:

Alberts, Dr D.S. and Hayes, Dr R.E., *Power to the Edge: Command… Control… in the Information Age*, 3rd Printing April 2005, CCRP, See URL: http://www.dodccrp.org

Alberts and Hayes, 2007, *Planning: Complex Endeavours.* CCRP, April 2007

Alberts, *The Future of C2: Agility, Focus and Convergence*, 12th ICCRTS, Newport, RI, USA, 2007 http://www.dodccrp.org/events/12th_ICCRTS/CD/iccrts_main.html

Smith, Dr E.A., 2003, *Effects Based Operations – Applying network centric warfare in peace, crisis and war,* Command and Control Research Program, USA

Please comment on the relevance of these works to you and future joint and coalition operations as you see it? Please identify what was the most significant point you found in each of these?

Please identify whether you have initiated, or you are aware of, any significant changes to the ADFs, or your countries latest, "Network Centric Warfare Roadmap" (2007) affecting future capabilities postulated by in the Defence Capability Plan of 2009 (See Publications on the Capability Development Group (CDG) website at www.defence.gov.au/capability), or your countries latest.

Please identify those tools you are sure that are being bought or developed for NCW, EBO and systems/munitions effectiveness. Are you sure others will understand the significance of this question to tailored effects and choosing the correct system/weapon for the effect required?

What is your experience of such systems being used in-service – in terms of usability, accuracy, validity, updating, supportability etc... What are the key practical issues to this being done right?

What do you see the affect of NEO will be to the aerospace mission environment?

Are you aware of the Service Oriented Architecture, Open Systems Architectures and US Joint Tactical Radios System (JTRSs) initiatives and the more recent Software Configurable Architectures (SCA). Please identify implications for future joint capabilities.

Are you aware of the US Banshee demonstrators and the USAF AFRL Weapon Data Link Architecture (WDLA) and Network Enabled Weapons initiatives with Society of Automotive Engineers and NATO? Please identify implications for future ADF capabilities such as system levels, third party targeting and network robustness.

What are the major issues being explored and/or demonstrated in the Experimentation and/or concept demonstrator programs that you are aware of?

Please identify any Experimentation in Exercises such as TALISMAN SABRE and Concept/Interoperability Demonstrations proposed to verify future operational concepts impacting this research. Please identify POCS who could elaborate on this further?

Please identify issues with future training for future capabilities.

Please identify any test or training ranges developments affecting the network enabling of future capabilities that you are critical.

In particular what are the issues with implementation of TENA / HLA / DIS / NexRI and iNET architectures etc on test and training ranges going to be for the US and Allies?

Please identify any issues with the introduction of directed energy weapons: ie high powered laser, HF, particle beams when using NEO.

Please identify any issues with improving the use of Modelling & Simulation with future complex adaptive capabilities throughout the capabilities life cycle.

What level of interoperability should all the capabilities and C2 systems you are involved with or are aware of have with Allies: common, interchangeable or compatible. Please also annotate for the information systems what level of interoperability is needed using the LISI model criteria, and why?

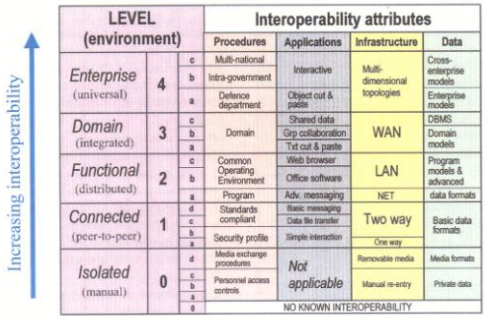

Figure 1. *The US DOD LISI Model.*

What is your understanding of the US Joint T&E Methodologies (JTEM) and Joint Mission Enabled Test Capabilities (JMETC) initiatives. How will it affect joint and coalition test, training & operations?

What issues are involved with achieving a ‘whole of life’ view for M&S, test, training and mission rehearsal and the L-V-C construct of the future?

Have you been involved with any case studies of the application of this code of best practice for experimentation to real world avionic mission system upgrades and to network enabled operations.

Familiarity with / Utility of Key recent References

Are you familiar with the US DOD Command & Control Research Program and able to comment on the utility to you/staff of Hayes and Alberts Experimentation CoBP (2002) and the NATO RTO C2 Assessment CoBP (2002)? Go on go to http://www.dodccrp.org for a wealth of relevant material from the CCRP. Based on any experience with applying such CoBPs, are there any 'lessons learned' and any areas you think now need to be expanded/improved upon?

Are you familiar with and able to comment on the utility to you/staff of the TTCP's Guide to Experimentation or GUIDEx (2006)? See URL: http://www.dtic.mil/ttcp/guidex.htm. Based on any experience with applying such a document, are there any 'lessons learned' and any areas you think now need to be expanded/improved upon?

Are you familiar with and able to comment on Nassim Nicholas Taleb's book: *The Black Swan, The impact of the Highly Improbable*, Penguin Books, 2007? It is well worth a read.

Other texts I would appreciate your comments on the potential relevance to the proposed research are:

- Dr Duncan Watts, *Six Degrees – the science of a connected age*, 2002, W.W. Norton & Company Ltd, NY, USA

- R. Heuer's book, *The Psychology of Intelligence Analysis*, 2003, Center for the Study of Intelligence, CIA, 3rd Edition, Washington DC ISBN 1920667000

- Paul Ormerod's book: *Why Most Things Fail…And How to Avoid it,* 2005, Faber & Faber Limited, London, Great Britain.

- Dr A Ilachinski's book, *Artificial War – Multi-agent-Based Simulation of Combat*, 2004, World Scientific Publishing Co, Singapore

- Dr Phil Ball's book: *Critical Mass, How One Thing Leads to Another,* 2004, William Heinemann, USA

Dan Gardner's book, *Risk: The Science & Politics of Fear,* Scribe Melbourne, 2008.

Are you able to comment on the impact Leadership styles, attitudes in a project, commitment to outcomes (the pig versus egg for breakfast scenario), cooperative/uncooperative relationships, organisational behaviours/dynamics can have on developing a capability?

Do you have any other comments, good ideas or cunning plans that you believe may be relevant to the research project at this early stage?

Please advise if you're willing to:

- do a personal interview to make sure the research accurately captures all your needs and perspectives on this sub-problem,
- your interest in being involved in future sub-problems and/or the Case Studies, and
- provide details of any other key individuals who you would recommend should also be participating in this research too – voluntarily or not!