NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

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RTO MEETING PROCEEDINGS MP-117 **SAS-039**

Analysis of the Military Effectiveness of Future C2 Concepts and Systems

(Analyse de l'efficacité militaire des concepts et systèmes C2 du futur)

Papers presented at the RTO Studies, Analysis and Simulation Panel (SAS) Symposium held at NC3A, The Hague, The Netherlands, 23-25 April 2002.

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RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

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- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS Studies, Analysis and Simulation Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

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Analysis of the Military Effectiveness of Future C2 Concepts and Systems

(RTO MP-117 / SAS-039)

Executive Summary

In 1998 The North Atlantic Treaty Organisation (NATO) published a Code of Best Practice (COBP) for Assessing C2, authored by SAS-002, which covered analysis of C2 at the ground forces tactical level in mid to high intensity conflicts. The inherent complexity of C2 (which involves both the information and cognitive domains), has presented the assessment community with challenges that are less well researched and understood and with a tool kit that is clearly lacking. The 1998 COBP, therefore, is being expanded by SAS-026 to help C2 analysts and decision makers deal with these new Information Age assessment challenges so that they can improve their ability to take on analyses of requirements, analyses of alternatives, research on new C2 concepts and capabilities, and support real world operations.

SAS-039 has been commissioned by NATO to conduct a formal review of the revised and extended COBP, and to review current analyses that demonstrate best practices in C2 analyses among member countries. The following materials contain both discussions of the revised and extended COBP, as well as best practices in current C2 analyses. In order to expand the COBP to reflect the full range and complexity of C2, SAS-039 solicited papers on the following topics:

- Operations Other Than War (OOTW)
- Novel Command and Control Arrangements
- Information Superiority Concepts
- Network Centric Concepts
- Distributed/Adaptive C2 Approaches
- Treatment of Cognitive Factors
- The Use of Experimentation

Analyse de l'efficacité militaire des concepts et systèmes C2 du futur

(RTO MP-117 / SAS-039)

Synthèse

En 1998, l'Organisation du Traité de l'Atlantique Nord (OTAN) a publié un code des meilleures pratiques (COBP) pour l'évaluation du C2. Etabli par le groupe SAS-002, ce document concernait l' l'analyse du C2 des forces terrestres au niveau tactique, dans le cadre de conflits de moyenne à forte intensité. La complexité propre au C2 (qui touche à la fois aux domaines de l'information et de la cognition), a mis les évaluateurs devant une tâche qui n'a pas été bien maîtrisée ni sur le plan de la recherche ni sur celui de la compréhension et pour laquelle il y a eu un réel manque d'outils. Par conséquent, le groupe SAS-026 est en cours d'étoffer le COBP pour 1998, afin d'aider les analystes et les décideurs en matière de C2 à faire face aux nouveaux défis de l'ère de l'information liés à l'évaluation, afin de leur permettre d'améliorer leur capacité à analyser les besoins et les options possibles, à mener des recherches sur de nouveaux concepts et capacités C2, et à soutenir des opérations en situation réelle.

L'OTAN a chargé le groupe SAS-039 de procéder à un examen officiel de la nouvelle version élargie du COBP et de passer en revue les études en cours des meilleures pratiques adoptées pour les analyses du C2 dans les pays membres. Les éléments qui suivent rendent compte des discussions sur la nouvelle version élargie du COBP ainsi que des meilleures pratiques en matière d'analyses du C2 . Pour que cette nouvelle version reflète l'éventail complet du C2 et toute sa complexité, le groupe SAS-039 a demandé des documents sur les sujets suivants :

- opérations autres que celles de guerre (OAQG)
- nouvelles dispositions de commandement et contrôle
- concepts de supériorité de l'information
- concepts réseaucentriques
- approches C2 réparties/adaptatives
- traitement des facteurs cognitifs
- recours à l'expérimentation

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Programme Committee

ORGANISING CO-CHAIRMEN

Dr. David S. Alberts
Director, Research and
Strategic Planning
ASD (C3I)
Room 3E172
The Pentagon
Washington DC 20301
UNITED STATES
Tel: +1 703 695 7183
FAX: +1 703 614 8060
E-mail: david.s.alberts@osd.pentagon.mil

Dr. Herbert K. Fallin
Division Chief
Operations Research and Functional Services Division
NATO Consultation Command and Control Agency
Oude Waalsdorperweg 61
PO Box 174
2501 CD The Hague
THE NETHERLANDS
Tel: +31 70-374-3060
FAX: +31 70-374-3069
E-mail:herbert.fallin@nc3a.nato.int

MEMBERS

CANADA
Valdur Pille
Canadian Representative
DRDC Valcartier/DRDC
Tel: +1 418 844 4000 (x4457)
FAX: +1 418 844 4538
E-mail: valdur.pille@drdc-rddc.gc.ca

FRANCE
Christian Manac'h
French Representative
DGA/CAD
Tel: +33 1 42 31 91 33
FAX: +33 1 42 31 91 75
E-mail: christian.manach@cad.etca.fr

GERMANY
Professor Reiner K. Huber
German Representative
University of the Federal Armed Forces
Of Germany
Tel: +49 89 6004 2206
FAX:+49 89 6004 3036
E-mail: huber@informatik.unibw-muenchen.de

NORWAY
Hans Olav Sundfor
Norwegian Representative
Senior Scientist, FFI
Tel: +47 63 807754
FAX: +47 63 807754
E-mail: hans-olav.sundfor@ffi.no

THE NETHERLANDS
Nicholas Lambert
Architectures and C3I Analyses Branch
Operations Research and Functional
Services Division
NATO Consultation Command and
Control Agency
Oude Waalsdorperweg 61
PO Box 174
2501 CD The Hague
Tel: +31 70-374-3603
FAX: +31 70-374-3069
E-mail: nicholas.lambert@nc3a.nato.int

Mink Spaans
Netherlands Representative
TNO-FEL
The Netherlands
Tel: +31 70 374 0211
FAX: +31 70 328 0961
E-mail: spaans@fel.tno.nl

UNITED KINGDOM
Professor James Moffat
UK Representative
Defence Science and Technology Laboratory (Dstl)
Tel:: +44 1252 455374
FAX: +44 1252 455062
E-mail: jmoffat@dstl.gov.uk

TECHNICAL ADVISORS

GERMANY
Dr. Andreas Tolk
Vice President Land Weapon Systems
IABG
Tel: +49 89 6088 2381
FAX:+49 89 6088 4015
E-mail: tolk@iabg.de

UNITED KINGDOM
Graham Mathieson
Technical Leader C3I & STAR
Centre for Defence Analysis
Tel: +44 239221 7732
FAX: +44 239221 7791
E-mail:glmathieson@dera.gov.uk

UNITED STATES
Dr. Richard E. Hayes
Evidence Based Research, Inc.
Tel: +1 703 893 6800
FAX: +1 703 821 7742
E-mail: rehayes@ebrinc.com

Dr. Stuart Starr
MITRE Corporation
Tel: +1 703 883 5494
FAX: +703 883 3397
E-mail: starr@mitre.org

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Introduction: NATO Code of Best Practice (COBP) for C2 Assessment – History and Overview

Dr. David S. Alberts
OSD/C3I
Pentagon 3E172
Washington, DC
UNITED STATES

david.alberts@osd.pentagon.mil

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NCW in the Royal Netherlands Army – Ambition, Potential and Dilemmas

BGen G.F.M.A Boers
Landmacht
Postbox 90711
2509 CS The Hague
THE NETHERLANDS

gfma.boers@mindef.nl

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Formulating the Problem and the Strategy for Solution

Prof. J. Moffat
Defence Science & Technology Lab (DSTL)
A3 Building
Farnborough GU14 0LX
UNITED KINGDOM

jmoffat@dstl.gov.uk

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Group Discussion on "Formulating the Problem and the Strategy for Solution"

Stuart Starr
MITRE
7515 Colshire Drive, MS N650
McLean, VA 22102-7508
USA

starr@mitre.org

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Measures of Merit (MoM)

V. Pille, R. Hayes and C. Wallshein
DREV/DND
2459 boul Pie XI North
Val Belair
Quebec G3J 1X5
Canada

valdur.pille@drev.dnd.ca

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Les scenarios dans le COBP

C. Manac'h and G. Lascar
DGA/CAD
16 bis avenue Prieur de la Cote d'Or
94114 ARCUEIL Cedex
FRANCE

georges.lascar@cad.etca.fr

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Communication présentée lors du Symposium RTO SAS sur « L'analyse de l'efficacité militaire des futurs concepts et systèmes de C2 », organisé à l'agence NC3A à la Haye, au Pays-Bas, du 23 au 25 avril 2002, et publié dans RTO-MP-117.

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Group Discussion on "MoM and Scenarios"

M. Spaans
TNO-FEL
TNO Physics and Electronics Laboratory
P.O. Box 96864
2509 JG The Hague
THE NETHERLANDS

Spaans@fel.tno.nl

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Human and Organisational Issues

Prof. Reiner K. Huber
University of Fed. Armed Forces Germany
Werner-Heisenberg-Weg 39
D 8877 Neubiberg
GERMANY

huber@informatik.unibw-muenchen.de

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Methods and Tools

Don Kroening
TRAC-FLVN
255 Sedgwick Ave
Fort Leavenworth
Kansas 66027-2345
USA

kroenind@trac.army.mil

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Data

Dr. Andreas Tolk
Virginia Modeling, Analysis & Simulation Center
Old Dominion University
7000 College Drive
Suffolk, Virginia 23435
U.S.A.

atolk@odu.edu

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Integrating Discussion on “Methods, Tools and Data”

Dr. D.S. Hartley III
Hartley Consulting
106 Windsong Ln
Oak Ridge, TN 37830
USA

DSHartley3@comcast.net

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Assessment Participants, Relationships and Dynamics

Nicholas J. Lambert
NC3A
AC3IA Branch ORFSD
P O Box 174
2500 CD The Hague
THE NETHERLANDS

nicholas.lambert@nc3a.nato.int

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Risk and Uncertainty

G.L. Mathieson
DSTL
C134, East Court
Portchester Hill Road
Fareham
Hampshire PO17 6AD
UNITED KINGDOM

Glmathieson@dstl.gov.uk

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Messages for Decisionmakers

Richard E. Hayes
Evidence Based Research Inc.
1595 Spring Hill Road, Suite 250
Vienna, VA 22182-2216
USA

rehayes@ebrinc.com

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Constructive Criticism from the Floor

Mark Sinclair
VERIDIAN
Information Solutions Division
2101 Executive Drive
Tower Box 51
Hampton, VA 23666
USA

mark.sinclair@veridian.com

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Introduction to Streams

Dr. David S. Alberts
OSD/C3I
Pentagon 3E172
Washington, DC
UNITED STATES

david.alberts@osd.pentagon.mil

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C2 Analysis of the Effectiveness of the Coyote LRESD

Eric Dorion
Defence R&D Canada – Valcartier
2459, Pie XI north
Val-Bélair, Québec G3J 1X5
CANADA
[1] 418-844-4000 (4257)

Eric.Dorion@drdc-rddc.gc.ca

Major Michel Gareau
Defence R&D Canada – Valcartier
2459, Pie XI north
Val-Bélair, Québec G3J 1X5
CANADA
[1] 418-844-4000 (4434)

Michel.Gareau@drdc-rddc.gc.ca

ABSTRACT

From October 28th to November 2nd 2001, DREV conducted a joint R&D and military experiment on the effectiveness of the new Lav-Recce Enhanced Surveillance Demonstrator (LRESD). The aim of this experiment was to assess whether Situation Awareness (SA) at the Command Post (CP) level was improved by adding a new suite of sensors on the standard Coyote vehicle, which constitute the enhanced version, namely, the LRESD. The information products produced by both Lav-Recce suites and forwarded to the CP were compared to the ground truth that was carefully designed prior the experiment. The timeliness of these information products is also considered. SA being of the utmost importance to the commander for his C2 duties, it was obvious that this aspect of C2 was to become our prime Measure of Effectiveness (MoE). Measures of Performance (MoPs) that would link both the systems level and the higher MoE were then chosen and strategies to evaluate them identified. This paper describes the experiment and how the experimental protocol was designed according to the principles and guidelines of the NATO Code of Best Practices (COBP) for C2 assessment. It will also clearly demonstrate the Measures of Effectiveness (MoEs) and Measures of Performance (MoPs) that were identified to be the key measures in the context of the experiment, and the considerations over human factors. Finally, the paper will describe the lessons that were learned during the experiment that were not necessarily controlled or expected with the positive and negative aspects that arose from them.

Key Words: *Experimentation, Situation Awareness, Measures of Merit, Information Systems.*

1.0 INTRODUCTION

Since 1997, numerous research projects have been conducted to improve the actual sensor suite of the Canadian surveillance vehicle called COYOTE. The enhanced version is called the Lav-Recce Enhanced Surveillance Demonstrator (LRESD). A secondary goal to these projects was to validate and test emerging technologies that exploit and help disseminate the information generated by the vehicle suite. The Defence R&D Canada – Valcartier (DRDC Valcartier) held an experiment in November 2001 that aimed at evaluating technological improvements to the Coyote (LRESD) and weigh the capacity to improve Command Post (CP) situation awareness when compared to a standard COYOTE suite.

This document describes the design of the experiment and some of the preliminary results. The NATO Code of Best Practice (COBP) [COBP, 1999] has been used as the general framework for our work. The first

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section of the document describes the theoretical background that supports solid and objective experimentation. The second portion deals with the design of the experiment, which is crucial for the identification of strong and weak aspects of the new suite. Also, the design of experiments is a process in which there is much to learn. As we will see, the experimental protocol was designed to reflect the state of the art in applying theoretical models of situation awareness. Whenever possible, quantitative and easy to measure metrics (e.g. system metrics) were preferred over qualitative and hard to interpret ones (e.g., observer notes). In the context of the experiment, measures that were taken in real time had higher priority than the ones that needed to be interpreted after the exercise. During the experiment, the emphasis was put at the vehicle/sensor level to better track and evaluate the passage of raw reconnaissance information up to its next hierarchical command level for further processing and analysis if required. It was hoped that by providing more and improved tools to pre-process and structure reconnaissance information directly at the vehicle level would improve the development of situation awareness at the CP level, therefore reducing redundancy of tasks and optimizing time for analysis and integration into the overall intelligence picture.

2.0 BACKGROUND THEORY

The goal of the LRESD-ISTAR experiment, as it is named, was to demonstrate that the new sensor suite better supports the operator in his task of generating information products for higher echelons in the chain of command, in the context of the Canadian ISTAR doctrine. Two quantities describe the information analyst's performance in a precise and complete way: The accuracy of the information he generates for higher echelons, (the Command Post) and the timeliness of his reports. Figure 1 illustrates how the analyst's performance is affected by information accuracy and timeliness. Clearly, region I is the one of high performance while regions II, III and IV are the ones where information products are inaccurate, untimely or worse, both.

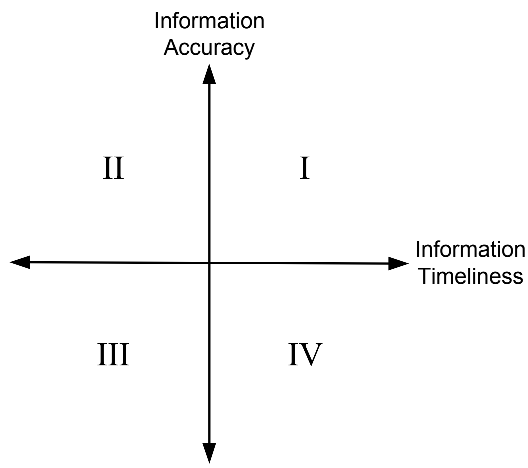

Figure 1: Analyst's Performance.

The experiment should demonstrate how analyst's performance is affected by the addition of the new sensors. Presumably, the performance should be improved, meaning that a point in Figure 1 would move in the general northeast direction. It is therefore important to understand in our context what is information accuracy and timeliness.

Situation Awareness as an MoE

All other things being equal, situation awareness is linked to the information product quality. While situation awareness is intimately linked to what our senses tell us, it is reasonable to think that sensors that extend our own capacities (hearing, viewing, touching, etc.) will help in increasing situation awareness and therefore increasing the information product quality. This reasoning constituted the main driver for LRESD-ISTAR experiment. Since, situation awareness as our prime Measure of Effectiveness (MoE) is the key element to determine the information product quality, it is important to well understand how it is defined and how it is influenced. According to Endsley [Endsley, 1988], situation awareness is the perception of the elements in the environment, within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. Figure 2 illustrates this definition.

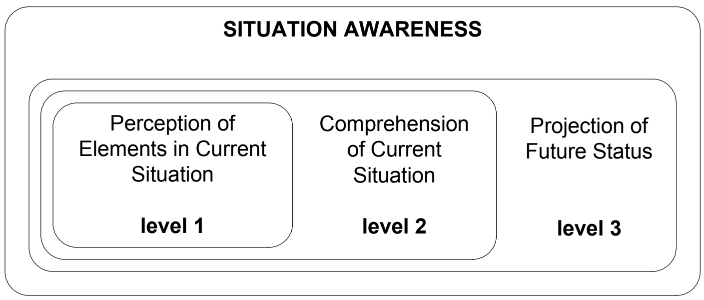

Figure 2: Situation Awareness.

In the context of the LRESD-ISTAR experiment, we were interested in determining whether bringing the new sensor suite would increase or not the operator's situation awareness. We argued that assessing level 1 of Endsley's situation awareness model would suffice for the task. We did not concentrate ourselves on level 2 and level 3, since the introduction of new sensors would not influence them. Furthermore, Jones and Endsley [Jones and Endsley, 1996] report that 76% of errors attributed to situation awareness of fighter pilots come from problems at level 1 of the model. This emphasizes the importance of perception in Endsley's model. It is important to note also that the model considers temporal aspects like elements that influence situation awareness. However, these aspects have their influence mostly on level 2 and 3 of the model and therefore are of less relevance to our case. Of course, temporal aspects were of prime importance to our experiment, but not in the sense Endsley defined them. We capture temporal aspects in the concept of timeliness as discussed above and in the next section.

Timeliness of Information

All other things being equal, the analyst's performance depends on the timeliness of his reports. Figure 3 demonstrates the concept of timeliness and 3 particular cases. Figure 3(a) shows the general case where information is useless before τ_1, useful for a $\tau_2 - \tau_1$ period, and finally too old after τ_2 (e.g., daily reports on refugees' situation). Figure 3(b) shows the case where information is highly pertinent but for a very short period of time (e.g., imminent bombing raid) and Figure 3(c) shows the case where information stays pertinent at all times (e.g., casualty reports). The analyst's performance is linked to his capacity of generating and forwarding information that is timely, meaning that his reports always fall under the timeliness curve of Figure 3. Whether this is an easy or difficult task depends on the shape of the curve.

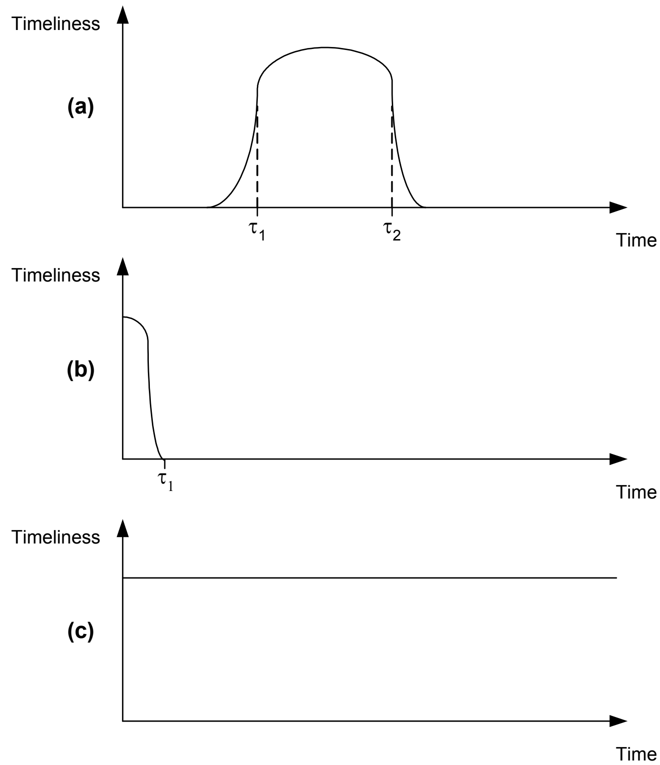

Figure 3: Examples of Information Timeliness.

While the concept of timeliness is easy to grasp, choosing metrics that will measure it adequately is rather difficult.

3.0 LINKING OUR MOE WITH MOPS

The NATO Code of Best Practice states that linking high-level metrics to system-level ones (MoEs-to-MoPs) is very challenging. We fully concur with this point. However, it is the only way by which one can achieve valuable C2 assessment. This section deals with the identification of 2 Measures of Performance (MoPs) and their linking to our prime MoE.

All measures in the context of the LRESD-ISTAR experiment must be taken with respect to the evaluation objectives that were stated in section 2. This also is consistent with the NATO COBP guidelines. It is therefore of prime importance to assess the analyst's accuracy of perception since it is a determining aspect of the information product's quality. The timeliness of this product has to be determined as the second parameter to the information product's quality.

In order to evaluate the analyst's quality of perception and the timeliness of the information product, we literally have to build the right instruments to measure them. We also have to choose carefully where these probes will be placed in the system. We need therefore to understand the nature of the observables which are the standard Coyote and the LRESD Coyote.

Description of the Coyote Vehicles

In essence, the Coyotes are surveillance vehicles equipped with a certain number of sensors that extend the perception's capacity of a human. Table 1 enumerates the sensors for both vehicles.

Table 1: Coyotes' Sensor Suites

Standard Coyote	LRESD
• Visible spectrum camera • Passive infrared camera • Radar	• Visible spectrum camera • Passive infrared camera • Radar • Active infrared camera • Acoustic sensor array • Coyote Battle Management System (CBMS)

In addition to its extended suite of sensors, the LRESD has a rudimentary information system that helps fusing information that comes from the sensors. This system is called "CBMS" (Coyote Battlefield Management System). It consists of a screen that centralizes sensor information, so it allows the analyst to focus on one screen instead of many. CBMS provides tools to manipulate and adjust the sensors of the LRESD and display their information on a map-based interface. It also allows the refinement and description of reconnaissance information items. Attachments such as video, annotated photos/imagery or even text documents can also be linked to the information items, thus enriching its "situation awareness value" for the next analyst.

Both Coyotes have means to disseminate information to upper levels in the chain of command (CP). Table 2 resumes these capacities.

Table 2: Coyotes' Information Dissemination Facilities

Standard Coyote	LRESD
• Paper reports (preformatted) • Voice radio link • Video recording • Structured messaging via TCCCS-IRIS	• Paper reports (preformatted) • Voice radio link • Video recording • Structured messaging via TCCCS-IRIS • High-bandwidth uplink to the CP via NTDR radios (full TCP/IP).

Communication links from the Coyotes to their respective CPs are shown in Figure 4. Both vehicles can transmit information by voice and data through the digital radio system "TCCCS-IRIS". However, transmitting data through TCCCS-IRIS requires the preparation of formatted messages in USMTF format mainly. We recall that in the context of this experiment, we do not want to focus on the treatment of information but rather on its detection (perception). For this reason, we denied the use of data transmission through TCCCS-IRIS, leaving the standard Coyote with voice transmission only. The LRESD is equipped with an NTDR radio that basically gives full TCP/IP capabilities over a 287 kb/s channel. At this rate, it is reasonable to transmit short videos and particularly overlays to the All-Source Intelligence Producer (ASIP). ASIP is a command and control information workbench prototype that supports the intelligence operator in his task. Basically, the information produced by the LRESD was sent over the NTDR link and reproduced on an ASIP overlay in the CP.

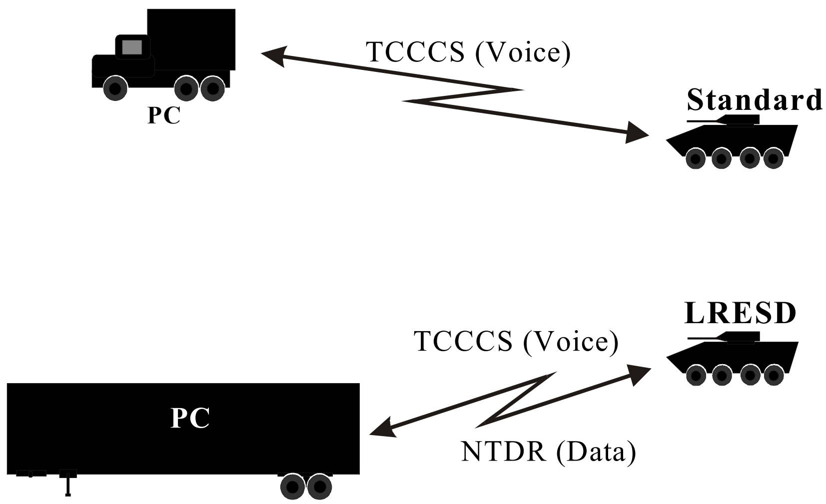

Figure 4: Communications Links.

Although the communications links of the 2 configurations are different (voice vs. data) and that the receiving ends (ASIP vs. CP analyst) are different also, there is no impact on our experiment because we chose to record the state of the information at the moment where the information products quit the vehicles and not the moment they arrive at the CP (or later). In fact, the use of ASIP fulfilled other goals that were of no relevance to this experiment. On the other hand, the information products quality was determined by a judge afterwards.

Coyotes Deployment

In order to verify the impact the new sensors and CBMS have on the analyst's situation awareness, it is important that all other parameters that might influence it be kept constant. One of these parameters is the position of the vehicles. Both vehicles were given the same zone of surveillance. Within this zone, events that would elicit responses from different sensors occurred. Although the vehicles were apart (about 100 feet), their sensor suites were collocated, giving equal chances of detection. Of course, the nature of certain events would not trigger equally both sensor suites, and that's the point of making the experiment. This is the case notably for acoustic events, which are only detectable through the acoustic array of the LRESD. Sensor detection does not necessarily mean human detection and it might occur that certain acoustic events would not be detected (and reported) by the intelligence analyst. The point was to find why. Of all the hard data that we obtained from this experiment, notes from passive observers were probably the most important source of discovery for improving our systems. We discovered hidden aspects of the system that had significant impact on the way information flow was influenced. Some of these aspects were good (e.g., inferring information from the toggling between 2 sensors), others were bad (e.g., overloading the analyst's job).

4.0 SYSTEM-LEVEL METRICS (MOPS)

The Coyotes and their information analysts constitute systems that accept inputs (sensor information) and give outputs (information product). In a simplified way, an output y(t) is a representation of the input with a certain scaling factor, and delayed by a certain period of time. So,

$$y(t) = a \cdot x(t - \tau)$$

Distortion Factor a

The scaling factor a represents the situation's quality of perception of the system (sensor suite + intelligence analyst). This distortion, which may be non-linear, depends on the quality of the sensor-analyst set. By setting the analyst's competence to a constant, the distortion factor a depends on the sensor suite quality. With a series of identical events presented to both Coyote vehicles, we obtained a direct measure of the quality of perception and therefore a measure of the gain in situation awareness. This measure depended on the sensor suites. In practice, this factor is evaluated in the CP by a judge as a function of the difference between the information reported and the ground truth. The distortion factor is evaluated along these guidelines:

- Object detected or not
- Correct identification of the object
- Accuracy of the reported position of the object
- Estimated object speed
- Assessed activity of the object
- Projected behavior of the object

Delay Factor τ

The delay factor τ is defined as the elapsed time between the moment where an event occurs and the moment where this event is actually reported to the CP by the information analyst. It is equal to the sum of the delay of sensor detection (τ_c), the delay of analyst detection (τ_d), and the delay of analyst information processing (τ_p). So,

$$\tau = \tau_c + \tau_d + \tau_p$$

We supposed that information would not be intentionally retained by analyst for over-processing. Also, we judged that sensor detection delays would be negligible when compared to the analyst detection and information processing delay. τ is influenced by several factors like the analyst's attention, sensors ergonomics, information ambiguities, information overloading, etc. It is important to understand that this delay is normal and that it only gains significance when compared to the timeliness profile of this event. For example, a delay τ situated between τ_1 and τ_2 in Figure 3(a) is perfectly acceptable, while a delay τ longer τ_1 than in Figure 3(b) is alarming. Timeliness profiles for each event (or group of events) were to be known prior the experiment in order to evaluate the analysts' performance against temporal aspects.

Practical Considerations

While a and τ were measurable by introducing probes at the right places in the system, we preferred using passive educated observers as the main measuring instruments for this experiment. "Passive" observers are non-intrusive agents. They do not interfere with the analyst's job, they do not help nor do they comment the analyst's behaviour. This is important since it would introduce significant distortion in both temporal and quality metrics. "Educated" observers know what events will occur, when they will occur. This prior knowledge enables them to focus their observations to what is important to note and therefore explain why certain delays are particularly long (e.g. an analyst distracted by something).

Someone might say that using humans as observers may introduce subjectivity to the outcome of the experiment. We argue that certain aspects of systems (including human-in-the-loop) are simply not possible to evaluate without observers. Two aspects of using observers must be avoided at all costs. The first is an observer with unclear objectives. He will observe things all right, but without any focus on the assessment objectives, the observations become useless. The second one is an observer in a mechanized role. By knowing the nature of the measures he takes, an observer can comment aspects of his measures, enabling statistical analysis after the experiment. If not, numbers will be numbers and some won't be explainable.

5.0 SUMMARY

While the data obtained in the three-day experiment is still being analyzed and that we cannot present fancy graphics yet, we still can talk about the lessons learned. First, we noted that the degree of integration of CBMS, the LRESD information system, was not sufficient to support efficiently the analyst's task in the vehicle. Indeed, the analyst had to jump from a sensor to another in order to acquire enough information and this lead to increased delays in the processing. Second, we noticed that sensor sweeping counted for a fair portion in the delay of detection, especially at nights. Fortunately, we were able to evaluate these delays enough for compensation. Third, the acoustic array is a sensor suite that triggers the interest of the analyst. At best, it gives the bearing and range of a certain target. The analyst must then rely on the other sensors to effectively confirm and identify the target. While this new sensor may help greatly the analyst by focusing his attention, the benefit of having an acoustic array may not have been measured with the metrics we chose. In fact, we feel that we did not measure it well. Empirically, our results show no benefit of having this type of sensor, but this is not because there is no benefit of having it. It was merely a question of choosing the right metrics. Fourth, there are events that are intrinsically hard to detect. Snipers on observation mission are one example. In this case, a reconnaissance vehicle is almost lucky to detect one even with the LRESD extended sensor suite. This inserted great distortions in our results. Fifth, giving new tools to the analyst has a non-negligible impact on the standard operating procedures (SOPs). New sensors mean new ways of interpreting information and therefore new ways of doing things. The analyst's job is impacted and parameters that should have stayed constant throughout the experiment might have varied without us knowing.

These are but a few things that we learned in this experiment. The application of the experiment protocol was a complex task given the many parameters and uncertainties typical to military operations. The NATO COBP helped us designing the protocol, particularly concerning the choice of metrics. Conducting experiments is a process that one can only learn through experience. It left us with many valuable lessons. We hope to have transmitted some of these to the reader.

6.0 REFERENCES

[COBP, 1999], *Code of Best Practice (COBP) on the Assessment of Command and Control* (Research & Technology Organisation (RTO) Technical Report 9AC/323(SAS)TP/4), (1999), Neuilly-sur-Seine Cedex, France: North Atlantic Treaty Organisation (NATO) RTO.

[Endsley, 1988], "Design and Evaluation for Situation Awareness Enhancement", In *Proceedings of the Human Factors Society 32nd Annual Meeting* (Vol. 1, p. 97), Santa Monica, CA: Human Factors Society.

[Jones and Endsley, 1996], "Sources of Situation Awareness Errors in Aviation", *Aviation, Space and Environmental Medicine*, 67(6), 507-512.

7.0 LIST OF ACRONYMS

ASIP	All-Source Intelligence Producer
C2	Command and Control
CBMS	Coyote Battlefield Management System
COBP	Code of Best Practice
CP	Command Post
DREV	Defence Research Establishment Valcartier
ISTAR	Intelligence Surveillance Target Acquisition and Reconnaissance
LRESD	Lav-Recce Enhanced Surveillance Demonstrator
MoE	Measure of Effectiveness
MoP	Measure of Performance

AUTHOR BIOGRAPHY

Eric Dorion is a computer scientist in the Metrics and Experimentation group (System of Systems section) at the Defence R&D Canada – Valcartier. He was the scientific authority of the LRESD-ISTAR experimental protocol. He is currently doing his master's degree on the performance of military distributed information systems. He is also doing a master's degree in business and administration (MBA) with a specialization in management information systems.

Major Michel Gareau is the land liaison officer in the System of Systems section at the Defence R&D Canada – Valcartier. He was the military leader of the LRESD-ISTAR experiment and is the military leader on many other similar projects, notably ASIP.

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Analysis & Evaluation of the Immediate Reaction Task Force (Land) Command and Control Concept: Applying the COBP

Mr Nicholas J. Lambert
Architecture and C3I Analyses Branch
Operations Research and
Functional Services Division
NATO C3 Agency
Oude Waalsdorperweg 61
PO Box 174
2501 CD The Hague
THE NETHERLANDS
[31] (0)70 374 3603

nicholas.lambert@nc3a.nato.int

Dr Umit Candan
Chief Architecture and C3I Analyses Branch
Operations Research and
Functional Services Division
NATO C3 Agency
Oude Waalsdorperweg 6
PO Box 174
2501 CD The Hague
THE NETHERLANDS
[31] (0)70 374 3602

umit.candan@nc3a.nato.int

ABSTRACT

The task facing the analytical team charged with evaluating the novel Command and Control (C2) concept of the HQ Immediate Reaction Task Force (Land) (IRTF(L)) was considerable. This paper highlights the approach taken and documents the analytical and data collection activities taken to utilise the exercises that were used by the HQ while it evolved the Concept. It also highlights a practical example of an attempt to implement the NATO Code of Best Practice for the Assessment of C2 in a real life C2 problem within the constraints of the study. The role played by Wargames, Simulations, Process analysis and Historical analysis in the evaluation are also mentioned.

Key Words*: Simulation, Wargaming, Concepts, Experimentation, Digitisation, Command and Control, COBP.*

1.0 INTRODUCTION

> NATO Military Function 01: Command and Control: *"The* ***organisation, process, procedures*** *and* ***systems*** *necessary to enable timely political and military decision making and to enable military commanders to direct and control military forces."* (NATO MC, Nov 1996)

Concept Development and Experimentation (CDE) for NATO was proposed at the Norfolk Conference in 1998 and was subsequently launched as part of the Defence Capabilities Initiative (DCI) at the Washington Summit. The NATO Military Committee (MC) tasked Supreme Allied Commander Atlantic (SACLANT) to report on the resource and organisational implications of developing the CDE process within the Alliance (SACLANT, March 1999). To permit a more accurate assessment it was decided that a test case should be used. The test case selected was the novel Immediate Reaction Task Force (Land) (IRTF(L)) command and control concept proposed as a mechanism to modernise the ACE Mobile Force (Land) (AMF(L)) (SHAPE PRX, May 1999). Supreme HQ Allied Powers Europe (SHAPE) was tasked with responsibility for

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the evaluation of the test case. The Operations Research Division of the NATO Consultation Command and Control Agency (NC3A) was asked to lead and provide the necessary scientific support.

The IRTF(L) concept was briefed to the Military Committee (MC) on 14 October 1999. The concept was noted and experimentation of the command and control aspects was sanctioned for a period from 1 June 2000 to 31 May 2001.

A permanent CDE Working Group for the test case was formed with members from the Strategic Commands; SHAPE and SACLANT, the NC3A and Regional Command NORTH. This group activates ad hoc sub-groups when required for specific tasks.

In accordance with CDE guidance, SHAPE produced a concept White Paper describing the concept within an operational context, the experimentation strategy to be adopted and the hypothesis to be tested (SHAPE PRL, Dec 1999). Using the White Paper, the NC3A produced an Experimentation Plan (NC3A, Feb 2000) listing the required analytical tasks and exercises that would be used in the evaluation of the concept, their connectivity and the projected level of effort required.

The experimentation plan was based around the data collected during a series of exercises. A total of three AMF(L)/IRTF(L) Exercises were originally identified and mandated by the MC as the primary vehicle for concept evaluation. Two more exercises, were added to the Experimentation Plan by the CDE Team (NC3A May, Oct, Dec 2000 and Mar 2000). As a result of a SHAPE recommendation and the cancellation of one of the original three exercises the experimentation period was extended until December 2001 by the MC. This allowed two more IRTF(L) exercises to be added to the expanded experimentation plan (NC3A, Sep & 11 Dec 2001).

The final report on the viability of the concept was made by SHAPE and NC3A in Dec 2001 (NC3A, 19 Dec 2001).

The evaluation of this concept was complex. The methods employed by the Analytical Team included; historical analysis, human factors research, the collection of data during Command Post and Field Training Exercises, process analysis, simulation and wargaming (Candan & Lambert, 2002; Lambert & Martel, 2002; Lambert, 2002; Spacie, Storr and Waddell, 2002).

2.0 THE NATO CODE OF BEST PRACTICE FOR C2 ASSESSMENT

From the outset of this project the Analytical Team made reference to the newly published NATO Code of Best Practice for C2 Assessments (RTO, 1999) and also to the summary version – the UK DERA Guide to Best Practice for C2 Assessments (DERA, 1999). Many of the tenets suggested in the COBP were noted by the team and put into practice within the constraints of the project. Some of the immediate lessons identified were also noted and incorporated into the revised COBP, in particular those relating to the participants in the project and the requirement for an iterative approach to problem formulation. This paper will attempt to illustrate the IRTF(L) project against the backdrop and headings of the COBP.

3.0 THE IRTF(L) COMMAND & CONTROL CONCEPT

3.1 ACE Mobile Force (Land)

The AMF(L) was created in 1960 as a rapidly deployable multinational land force to act within NATO's Area Of Responsibility (AOR) as a political signal and deterrent (NATO MC, 1970). Originally envisaged as a brigade group with the strength of approximately 5000, it was composed of a HQ structure designed to command three light infantry battalions supported by the appropriate Combat Support (CS) and Combat Service Support (CSS) elements. In order to operate within the environments of the NATO AOR (including arctic and mountainous), the force pool from which the appropriately equipped and trained force of 5000 would be drawn has expanded over the years to a strength of nearly 19000 troops. HQ AMF(L) is under the Supreme Allied Commander Europe's (SACEUR) direct command with national contributions under national command until deployed. Key elements are at 72 hours Notice To Move (NTM) for Article 5 operations, with the remainder at 7 days NTM. In practice, key elements are ready to undertake operations by G[1]+5, the remainder no later than G+13.

The AMF(L) is NATO's unique instrument to project cohesion, solidarity and resolve through its immediate readiness, multinationality, and versatility. It is a highly trained formation ready for deployment in deterrence operations, conflict prevention, humanitarian missions and peace building operations. Its diverse and truly multinational force pool assets gives it great flexibility as well as the ability to be tailored for different situations and to undertake varied tasks.

3.2 The IRTF(L) Concept

The proposed a new concept for the AMF(L) is entitled the Immediate Reaction Task Force (Land) (IRTF(L)) (SHAPE PRX, May 1999). The overall aim of this concept is to provide SACEUR with a credible and immediately available multinational force, of up to division in size, which can intervene, as appropriate, in both Article 5 and non-Article 5 crisis response operations (CRO) as directed by SACEUR.

The IRTF(L) can deploy its lead elements within 72 hours and be operational on the ground with a HQ and lead companies within 7 days and be operational in 14 days with six manoeuvre battalions, followed by the entire division-size IRTF(L) in place within 3 weeks. Once deployed the IRTF(L) can function in a variety of roles from an independent initial entry force to an enabling force for a larger formation. IRTF(L) represents a credible military force and political tool that demonstrates the solidarity and resolve of NATO in all types of operations.

The IRTF(L) concept is predicated on the enlargement of AMF(L) from brigade size up to division size with a single streamlined headquarters and a chain of command using Task Groups.

The amalgamation of the division and brigade level HQs will result in significant savings in HQ support personnel and infrastructure requirements. In addition there would be personnel savings, as only approximately 255 HQ staff would be required for HQ IRTF(L)[2] as opposed to the 320 required for a traditional HQ structure of three brigade HQs and one divisional HQ. Utilising a significant degree of augmentation, the HQ Peace Establishment (PE) would be designed to provide the nucleus for rapid deployment up to brigade level, whilst retaining the ability to expand to command a division level formation

[1] G Day is the day the NATO Activation Order (ACTORD) is issued.

[2] Figures of 200 and 270 can also be used – depending on how the staff of the HQs concerned are categorised and counted.

when required. To enable this however small increases in the current Peace Establishment (PE) of the AMF(L) and major increases to the Crisis Establishment (CE) would be required. The fully manned IRTF(L) would operate on a mix of $^{1}/_{3}$ PE to $^{2}/_{3}$ CE.

The HQ concept will be empowered by information technology, thereby solving the span of command problems. The information sharing, message handling and common situational awareness through the use of a Battlefield Management System (BMS) will be implemented within the two levels of HQ IRTF(L) and also within the Bn Command Posts (CPs). To enable this, tactical communications of longer range than currently available to traditional brigade or divisional sized formations will need to be used (perhaps utilising satellite communications to overcome line of sight challenges) to allow communication from the divisional HQ directly to the battalions and divisional troops.

The IRTF(L) concept proposes a restructuring of AMF(L) to provide an organisation that has the flexibility to grow from a brigade to a divisional sized force. The HQ Command and Control (C2) is of a modular design with Task Groups (TG) responsible for the planning and controlling of ground manoeuvre units. TGs A-C operate as cells within the divisional Joint Operations Centre (JOC). Some TG staff are also integrated into the division staff as illustrated in figure 1 below. All CS and CSS remain controlled at divisional level. The current G Staff nomenclature should be changed to a Joint prefix indicating a divisional level of command with an inherent capability to plan for and control joint assets within an assigned area of operations.

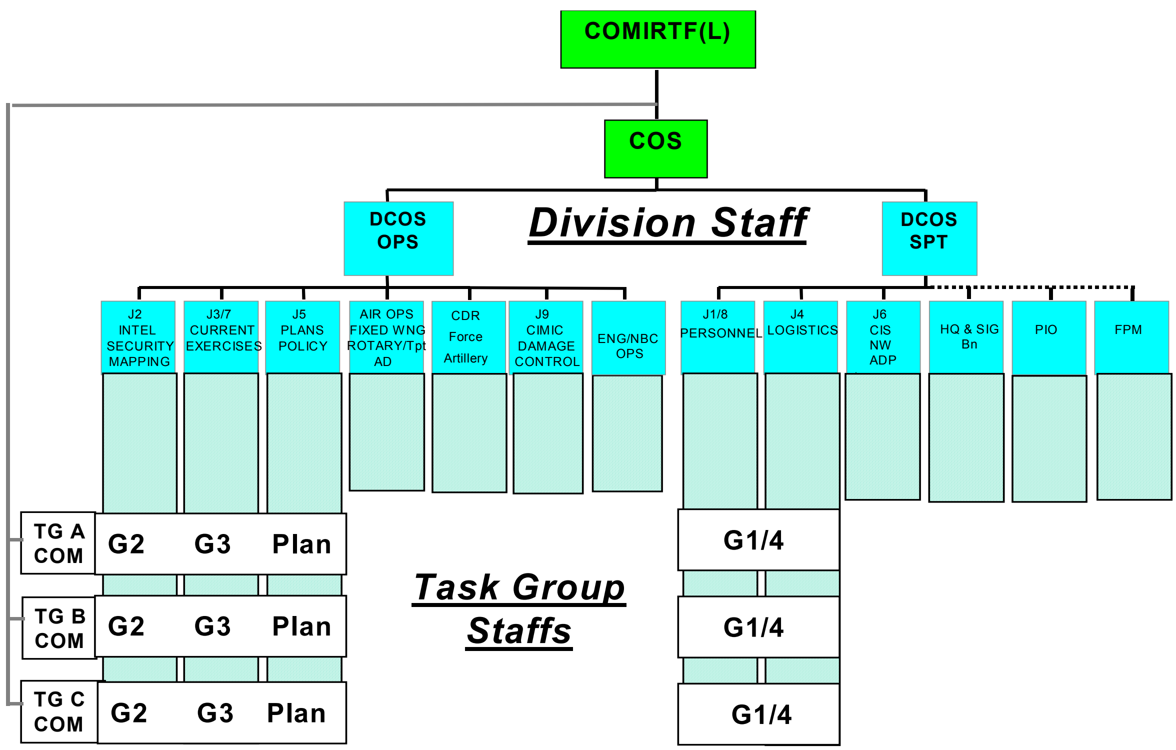

Figure 1: The IRTF(L) HQ Organisation.

Figure 2 illustrates the overall IRTF(L) structure with the manoeuvre TGs, Divisional Troops (responsible for force protection, deep attack, combat support and combat service support), and the Headquarter and Signals battalion. Echeloning heavier combat assets such as mechanised and armoured units can further increase the capability of the formation as and when needed.

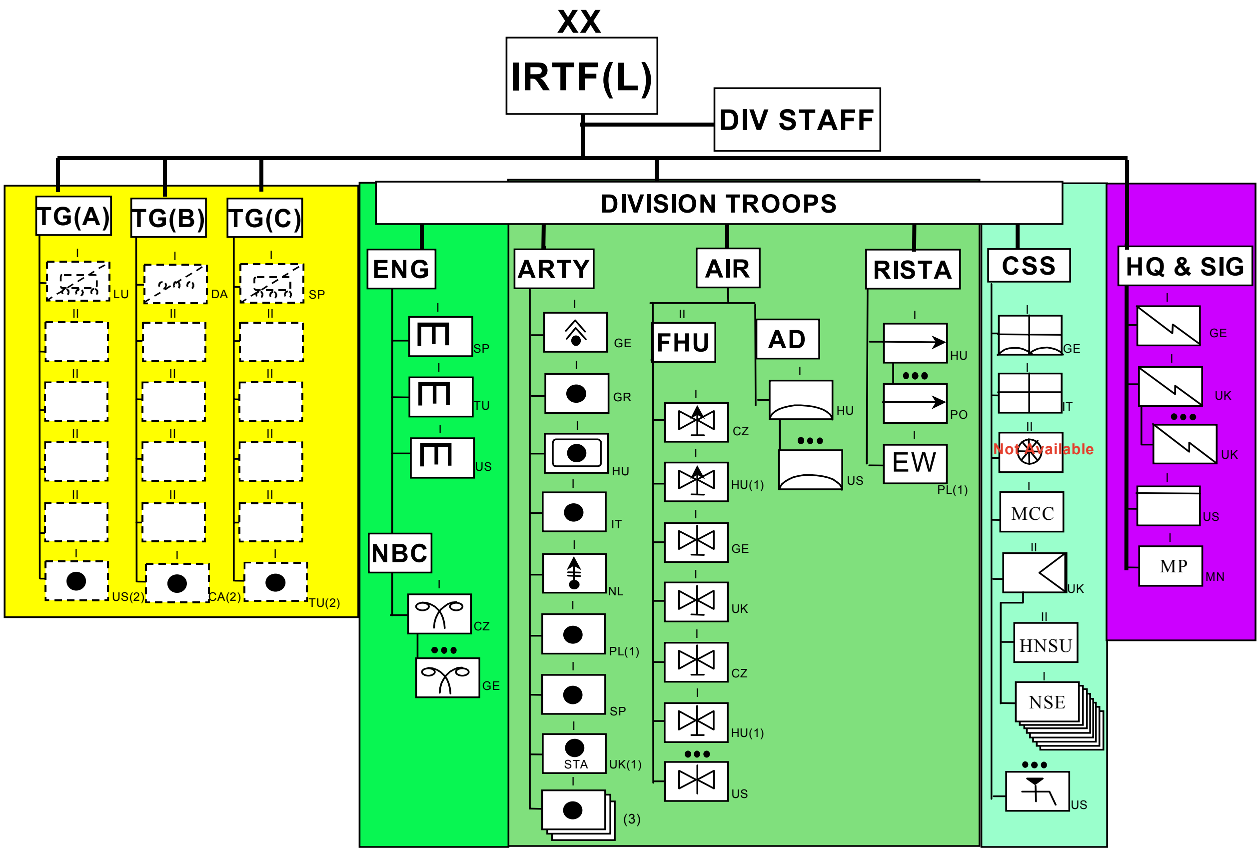

Figure 2: The IRTF(L) Task Organisation.

In summary, the key points to this concept are:

a) Flattened Headquarters structure:

(1) Increased span of control, from 3-5 Infantry Battalions to 9-12 Infantry Battalions.

(2) Task organised to provide a wide spectrum of utility.

(3) Without increasing the staff size to the requirement of conventional structures.

b) Digitisation

(1) Battle Management System (BMS), allowing a common view of the battlefield, from battalion to division.

(2) Use of technology to expand span of control.

(3) CIS and SATCOM to resolve challenges of span of command and control and range of communications, to cover increasingly disparate forces.

4.0 PROBLEM FORMULATION

Problem formulation was a continuous process throughout the life of this project (as is indicated in the COBP). It is probably fair to say that it was only after a year of looking at the problem that the team fully understood the problem space. This coincided with a revision of the solution strategy, the tools, methods and data used and the expertise used to support the Analytical Team. The essential elements of the formulated problem are, a precise statement of the question, and a list of the independent variables and High Level Measures of Merit (MoM). A full understanding of the assumptions and constraints on both the problem and the circumstances of the project are also required. With respect to this project these are below.

Using the CDE approach, the IRTF(L) C2 Concept evaluation required testing of a hypothesis built to reflect the objective of the concept. The Study Team developed the following hypothesis for the purposes of this study:

"By structural redesign, procedural modification and exploiting CIS innovation it is possible to create a multinational HQ that fulfils both brigade and division level C2 functions, and that is capable of conducting crisis management and crisis response operations." (SHAPE PRL, Dec 1999)

Testing of this hypothesis involved assessment of a subject in which three sets of variables changed simultaneously. These sets are; the mission spectrum, the organisational structure and the technology. This concept suggested that the IRTF(L) mission spectrum was to enlarge, with operations of different nature compared with that of AMF(L)'s. The HQ organisational structure, including its manning and procedures, needed to change significantly to reflect the requirements and aspirations of the new C2 concept. The third set of variables related to the introduction to the HQ of a BMS and SATCOM capabilities. During this evaluation the HQ organisational structure was the main variable. This was because the mission spectrum variable was able to be largely kept still for the duration of the trial, through the HQ AMF(L) exercise programme (which concentrated on traditional warfighting Article 5 Operations). Additionally the technological variable could also be kept still. This was achieved through:

a) The introduction of the current version of the Royal Netherlands Army Integrated Staff Information System (ISIS). The BMS and Tactical Messaging System (TMS) were loaned (with training and equipment) to the HQ AMF(L) for the duration of the trial. No significant changes to the capabilities offered by the BMS and TMS were made during the trial.

b) The simulation of the desired communications capabilities during the exercises. This was achieved through the use of landline in the place of SATCOM and the enhancement of the AUTOKO 90 radio to a bandwidth of 64kbps. This allowed battalion CPs to access to the same databases and servers as the division and TGs.

The time frame for the evaluation was tight. The mandate for the evaluation was to commence from the notation (14 October 1999) and the trial (in which there was something tangible to evaluate) was to last from June 2000 and report at the end of May 2001. This was later extended to December 2001.

Although the IRTF(L) C2 Concept was clearly described in outline, the CDE Analysis Team were surprised to discover after the commencement of the study that the description of the concept (SHAPE PRX, May 1999) was the only documentary record. Consequently the detail required for evaluation (and also for implementation by the HQ) was not available. As a consequence the Analytical Team were faced with the need to develop an objective method to collect data from and to evaluate an evolving concept.

At the beginning of the trial the AMF(L) was a light brigade HQ, equipped and operated in the traditional manner (circa 1970). In the period between the initial preparatory exercises (March and May 2000) and the first IRTF(L) exercise ADVENTURE EXCHANGE 2000 (Sept 2000), the HQ AMF(L) had to be transformed into HQ IRTF(L) (circa 2000). This involved considerable effort from the HQ staff and external NATO and national agencies:

a) Identification, reception and integration of the additional Voluntary National Contributions (VNCs) into the Peace Establishment (PE),

b) Bids for and reception of the additional Crisis Establishment (augmentees).

c) Complete re-design and (in some cases re-equipment) of the structure of the fielded HQ Tactical Operations Centre (TOC).

d) Rapid introduction of the ISIS CIS into the IRTF(L) TOC and battalion CPs, and a rapid training programme for the PE and CE on ISIS.

e) The establishment of the exercise communications to simulate the "future" communications.

The HQ AMF(L) is (as has already been explained) part of the Immediate Reaction Forces. As such it is on very short notice to move and needs to train with its subordinate units almost continuously. Throughout the trial the PE core of HQ IRTF(L) remained on an operational status (as the brigade sized AMF(L)), and thus the experimentation was conducted on an operational HQ.

As the reader may have already noted, this concept was mandated by the MC to be evaluated using the AMF(L) training exercises as the primary vehicle. These exercises occur two to three times per year from winter training in Norway to the plains of Greece and Turkey. They range from full scale brigade sized field training exercises (FTX) to command post exercises (CPX) – which may be also field based. The practical issues in organising, transporting, training and administering an *adhoc* exercise evaluation team on such exercises should not be underestimated.

The CDE team was completely *adhoc*. Team membership varied considerably throughout the duration of the project – although thankfully the core (the project leader from SHAPE and the two NC3A analysts) remained static. Support was sought for and generously provided from many quarters, the Observers were recruited and mustered by Regional Command NORTH from its subordinate commands, analytical and observer staff were provided throughout by DERA/DSTL and for the exercises by US Joint Forces Command and the German National Defence University. Data collection software support was initially provided from SACLANT[3]. Project funds were requested from and sometimes provided by both Strategic Commands (SHAPE and SACLANT). These were used for contractual support.

As part of the problem formulation phase(s) of the study, the Analytical Team conducted Red Teaming of the overall concept and also reviewed experiences in the removal of a level of command (Spacie, Storr & Waddell, 2002). The relevant period was from WWII onwards. The conclusions from this series of historical analyses were that:

a) Rarely – if ever, has a HQ concept been fully developed and tested before being imposed.

b) Where significant structural changes have been made, they have usually been imposed by decree from above. Such changes have also only ever been accompanied by broad organisational and procedural guidance.

[3] HQ SACLANT Programs & Research Branch (HC-53) – SACLANT OA.

c) Human – NOT technological issues dominate. This includes staff responsibilities, relationships, continuity, training and teamworking issues. In nearly all of the examples – these human issues were overlooked when imposing organisational changes on HQs. In trials following the reorganisation – it was these human issues that forced the rejection of the concept. The biggest reason seems to have been Span of Command.

d) Where new technology was part of the new concept – the novel HQ concept would almost always be rejected before the new systems were properly introduced. It seems however, unlikely that technology would have stopped the rejection of the concept – but might have mitigated some of the problems.

e) It was rare that staff roles and the pressures acting on staff as a result of the structural changes were ever reviewed.

f) There is a strong suggestion that the size of a HQ is inversely proportional to its effectiveness.

The problem facing the Analytical Team was multi-variable, multi-faceted and required multi-disciplinary approaches. In addition, the IRTF(L) C2 Concept had the characteristics of being multi-national and multi-organisational, with multiple stakeholders.

5.0 SOLUTION STRATEGY

The MC had directed the use of AMF(L) and IRTF(L) FTX and CPX for the evaluation of the IRTF(L) C2 Concept. These were training exercises with the primary aim of training the components of the AMF(L) force pool. The initial Experimentation Plan (NC3A, Feb 2000) was produced to gather together other activities (including simulation) to support this exercise centric approach. The initial method used by the Analytical Team was to try and directly measure the Measures of Merit (MoM) on exercise (as this was the primary vehicle for evaluation). In particular the intent was to try and objectively measure the Product Assessment MoM such as timeliness and quality. Directed observations backed up by structured interviews with customers of the HQ processes were therefore used throughout the study to gather information that would lead to an evaluation based on these MoM.

Rapidly however, as the CDE team gained experience in data collection and also worked further on the problem formulation, the MoM associated with the viability and sustainability of the processes of the HQ became more important. After the first IRTF(L) exercise in September 2000 (ADVENTURE EXCHANGE 2000) the solution strategy was adjusted to become more simulation centric. This methodology is schematically depicted in Figure 3. The major components of the method were:

a) Process Definitions. As the HQ processes and organisation evolved during the initial two IRTF(L) exercises, the Observers were used to collect the process information in the form of schematic diagrams and data (i.e. for each task, the resources and information used, location, duration, predecessor and successor activity were recorded). These process diagrams and data collected were then analysed and fed back to the HQ for review. Following a series of collective workshops an agreed working set of processes was reached with the HQ staff. The Commander IRTF(L) then halted further development of the HQ processes and organisation. This set of steady state processes were used in within the solution strategy:

   (1) As reference for the creation of HQ Standard Operating Procedures (SOP)[4].

   (2) As a data source for the HQ process simulation.

[4] Several HQ branches used the diagrams or subsets of the diagrams as the SOPs.

(3) As a reference for the observers in the final exercises to check adherence to the SOPs.

(4) To create "job descriptions" for the HQ staff (i.e. a listing of process elements by resource). These were of particular utility to the observers in the final exercise.

b) <u>Process Simulation.</u> A discrete event simulation model was developed to simulate the HQ "trigger-process(es)-product" cycle and to evaluate the workload of staff. The model developed was scenario a-specific. The processes and resources simulated were selected through analysis in parallel to the HQ process workshops. In essence the main processes of concern were those that crossed functional areas – and those resources (HQ staff) involved in them. Staff represented within these areas were either directly involved in the cross functional processes, deputising or providing key support. Other processes and resources simulated were modelled only to the extent to represent their ability to pull the resources of concern (around 80 key posts in the HQ) out of the key processes. The scenario specific triggers and descriptors on these HQ processes were identified and prepared as scenario input files. The simulation enabled measurement of the HQ functional area and individual staff officer workloads, the duration it took the HQ to produce its main products (while a number of different processes were being executed), and the potential bottlenecks in the HQ. These results could be split into scenario and scenario independent effects. The other key utilities of the simulation were to gain an understanding of the dynamics of the new HQ and at the end of the study – to place the Observers at points of concern in the final exercises.

c) <u>Wargames.</u> In order to populate the simulation scenario input files, statistics on the triggers and descriptors of the HQ Processes needed to be generated and collected. Three wargames were conducted. The method developed was manual, producing results only to a level of detail required to identify which HQ processes would be triggered. The gaming method was implemented as an event stepped game – resulting in a series of briefings to key HQ Staff of a developing situation. Following a tactical deliberation, the processes that would have been triggered within the HQ were recorded and skeleton products such as fragmentary Orders and Operational Orders were produced as input back to the game. The resulting series of triggers and other data were subsequently analysed and used to derive a scenario specific operational tempo for the Simulation. This information was also used as advice on the appropriate operational tempo required for the STAFFEX and final Exercise in Turkey.

d) <u>Historical Analysis.</u> In order to confirm the performance of the HQ IRTF(L) in warfighting CRO, historical analyses were also conducted to complement the data derived from wargames and exercises. The historical cases selected for this purpose were from the Land Campaign of the Falkland Islands operation in 1982. Using the original divisional, brigade and battalion/commando HQ Logs, a database was populated with the frequency of tasks that were submitted to brigade and division during the operation. These were then mapped onto the triggers of the HQ processes of the IRTF(L) to produce a scenario specific operational tempos for the simulation.

e) <u>Expert Judgement.</u> Throughout the study the simulation results and observations conducted during the exercises were complemented by expert judgment. These were from experts in command function and in the human factors relevant to IRTF(L). The most of the observers were also Subject Matter Experts (SME).

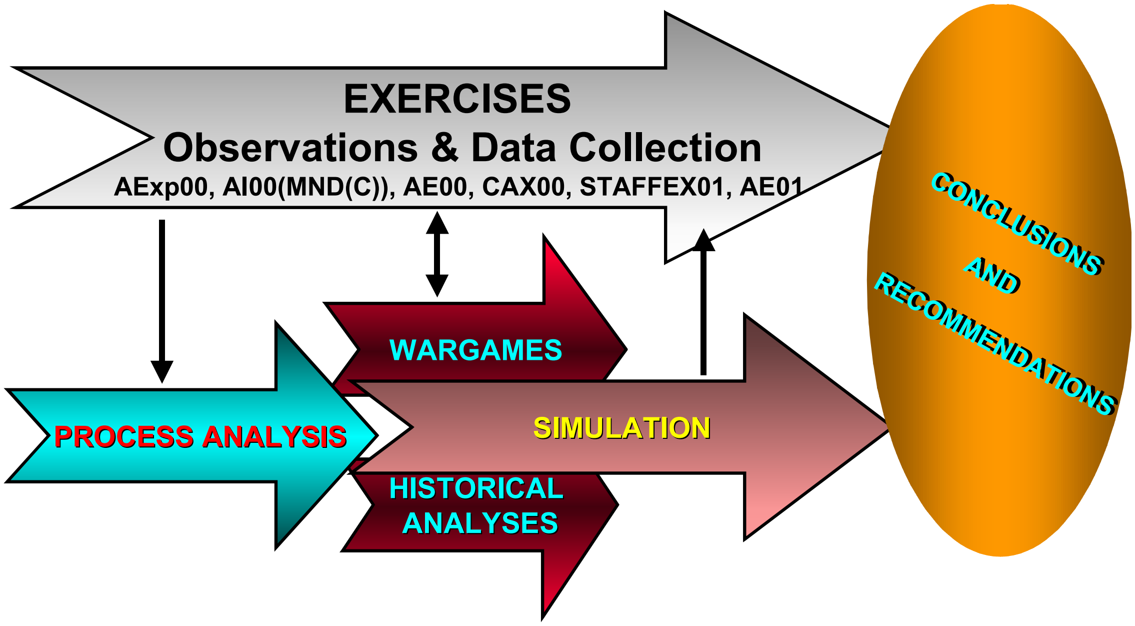

Figure 3: Study Methodology.

6.0 MEASURES OF MERIT

MoM were required to test the study hypothesis. One option was to only evaluate the overall performance of the HQ in terms of its effectiveness in relation to the performance of conventionally structured HQs. This approach alone was found to be of limited value. It was expanded to include the evaluation of the internal mechanisms of the HQ, and its overall performance.

The purpose of a HQ is to produce products to satisfy the requirements of its customers. The customers are, depending on operational circumstances, the commander, flanking, superior and subordinate formations, and other organisations. 'Products' take different forms, but could, for example, include as recommendations to the commander in his decision making, reports to higher commands, orders to subordinate commands etc. The HQ products are produced by the execution of a series of staff processes (situation assessment of the available information, preparing and staffing directives, course of action analyses etc). These processes are triggered by events (new mission, change in enemy forces, change in operational situation, etc). The HQ Staff executes these processes according to established SOPs.

By measurement of this 'trigger-process-product' cycle, a series of MoM can be developed that will ultimately help link the new C2 structure with the quality of the 'products', and thereby indicate the viability of the concept. The major MoM used in this study can be divided into two levels:

a) Product assessment (i.e. Customer Satisfaction).

   (1) Product timeliness to meet operational requirements (MoCE)[5].

   (2) Product quality in terms of its content, accuracy, relevancy, etc (MoCE).

[5] Using the MoM Classification of the NATO COBP: MoCE = Measure of C2 Effectiveness – showing the impact of the C2 System within the operational context.

b) Command function and internal staff processes (i.e. viability and sustainability of HQ processes).

(1) Compliance with the Principles of Command (MoP)[6].

(2) Compliance with the Organisational Principles (MoP).

(3) Staff Workloads (MoP).

(4) Compliance with SOPs (MoP).

(5) Co-ordination opportunities between different command levels (MoP).

(6) Co-ordination opportunities between different HQ functional areas (MoP).

(7) Degree of Situational Awareness (MoP).

Although there are strongly implied links between the two levels, direct causal links are not clear. For example, systemically high staff workloads in specific posts coupled with poor systemic opportunities for co-ordination between specific functional areas in the HQ, will almost certainly produce poor quality and late products – how many of these bad products however will actually affect the operation and to what magnitude is very difficult to establish[7].

Most of the MoMs above however are measurable individually. Within the above solution strategy the simulation helped establish b(3) directly whilst assuming that b(1, 2, 4, 5, 6, and 7) were conducted perfectly. Using the output of the simulations the wargames could also help establish a(1), whilst assuming all other areas were conducted perfectly. Process analysis also allowed an understanding of b(5) and b(6). Expert Judgement was used for b(1) and b(2). However, the only way to bring all of the MoMs together was in the live situation of the final two IRTF(L) exercises (NC3A, Sep & Dec 2001). In these, data collection and interviews with the customer's of the HQ processes provided the primary MoCE (a(1) and a(2)), whilst observation within the HQ proper at key points and resources – as identified by the simulations – provided data and SME assessments for the MoP.

7.0 HUMAN FACTORS AND ORGANISATIONAL ISSUES

The human and organisational implications of the IRTF(L) C2 Concept were the central issue that the Analytical Team tried to address in problem formulation and solution strategy. The human issues implied by the new C2 Concept were:

a) An increase in the span of command (although potentially mitigated through the use of TGs).

b) An increase in the size of the area and distances over which leadership has to be exercised (i.e. the superior command visits to battalions and divisional troops).

c) An increase in the span of control (especially with respect to the divisional staffs controlling the increased divisional troops and receiving the combined reports and intelligence directly from the 9-12 battalions and divisional troops).

d) The introduction of the requirement for some HQ Staff to have to simultaneously think at two levels of detail (brigade and division).

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6 Using the MoM Classification of the NATO COBP: MoP = Measure of Performance – focus on the internal system structures, characteristics and behaviour.

7 From observations during the exercises some poor quality and late products have the potential to have catastrophic effects.

e) Changes to the organisational structure of the HQ (i.e. the introduction of a "J" Staff structure, the use of 2x DCOS, a COS, TG Commanders, the embedding of TG Cells into the JOC, the incorporation of TG officers into divisional functional areas and the establishment of an Offensive Support Group).

f) Changes to the procedures of the HQ (i.e. the introduction of parallel planning processes and parallel adjustment procedures between TG and divisional levels in J3 and J5).

g) Introduction of new technology (with the required training overhead and radical change in culture from 1970s to 21st Century methods of sharing information).

h) Changes to the size of the fielded HQ – from a staff of around 75 (AMF(L)) to 255 (IRTF(L)).

i) Changes to the balance of permanent staff in the fielded HQ from the AMF(L) ($^2/_3$ PE: $^1/_3$ CE) to IRTF(L) ($^1/_3$ PE: $^2/_3$ CE).

As historical research had revealed that Human Issues were the prevalent factor in the rejection of novel C2 concepts, attempts were made initially to incorporate human issues into the HQ process simulations, to allow the investigation of these issues under "controlled" conditions. Human factors were studied to establish what human issues should be, or could be, represented explicitly within any process simulation of the HQ. The data were categorised into whether the factor acted on the commander or the HQ Staff (or both), the relative importance the factor would have when IRTF(L) echeloned from brigade sized force to a division. The data were also assessed on whether each factor could be represented within a simulation, or whether a static comparison or the use of Military Judgement/best practice would be best used. In most cases the data identified proved to be impractical (impossible) to collect/define and reliably relate to the relative influence on the HQ processes. Apart from data types such as frequency of task arrival and number of subordinates, all other factors (such as the impact of knowledge and experience of the staff, training level and familiarity of augmentees) would have to be left to SME judgement by the observers on the final two exercises. This key finding clarified the role of simulation to that of simply providing the evidence of workload and complexity of tasks faced by individuals – and to the identification of bottlenecks.

All of the above human and organisational implications of the IRTF(L) C2 Concept were investigated during the study – in particular these were studied by the observers and consultants whilst on the exercises.

Throughout the main evaluation period the command team and senior key HQ Staff remained in post. This provided a valuable constant to the study – as command style (organisational and risk styles) and orders style (degree of detail given to subordinates etc) can vary considerably. The randomness induced to the HQ's performance from exercise to exercise with respect to the presence of ever-changing augmentees however, should not be underestimated (and in this case provided the biggest single variable).

8.0 SCENARIOS

The main source of scenarios for the study were the AMF(L) training exercises. The terrain types, OPFOR capabilities, type of operations and tempo of these scenarios did not however always reflect the characteristics of the capabilities of IRTF(L) or the operations that it was projected to have been employed in. This was a factor that was outside the control of both the HQ and the CDE Analytical Team.

With respect to the scenarios used by the wargames the original intent was to address this problem and utilise vignettes from the collection of NATO Bi-SC Defence Requirement Review (DRR) scenarios, as these would provide the breadth of scenario conditions, OPFOR characteristics and environments that the IRTF(L) could have been employed in. Unfortunately, due to the gruelling exercise schedule of HQ AMF(L) there was no time available for the HQ Staff to conduct the additional work to prepare for anything other than vignettes developed within the scenarios of the forthcoming exercises. Using these exercise scenarios therefore, situations that were as realistic as possible to the capabilities of the IRTF(L) were developed for the wargames by the military staff supporting the CDE Analytical Team.

The Analytical Team were however, determined to try and confirm the performance of the HQ IRTF(L) in war-fighting CRO. Therefore historical analyses were also conducted on the Land Campaign of the Falkland Islands operation in 1982. Despite the passage of time this operation was still relevant and contained nearly all the features that the IRTF(L) C2 Concept might encounter in a CRO. The features of importance were: a light infantry *adhoc* force with limited organic CS and CSS resources, deploying as a brigade sized entry force echeloning to a divisional sized force on a Joint out of area operation of short duration, against a numerically superior enemy.

In summary, although much reduced in scope and number, the scenarios that were studied using the simulation covered a fairly broad spectrum of the IRTF(L)'s warfighting spectrum. The table below summarises the mix of tasks performed per scenario:

Table 1: Light Infantry Formation Tasks Performed in each Scenario

Tasks of a Typical Light Infantry Formation	Wargame 01 Main Defence I 3x TGs	Wargame 02 Main Defence II with restoration of NATO Territory 3x TGs	Wargame 03 Covering Force & Main Defence I 2x TGs	Beachhead and Goose Green. 21-30 May 1982 1x TG	Attack on Port Stanley 11-14 June 1982 2x TGs
Flank Protection	X		X	X	X
Key Point Defence	X		X	X	
Securing a Line of Departure	X	X	X		X
Main Defence	X		X		
Rear Area Security		X		X	X
Infiltration		X			X
Air Mobile Raids		X			
Deception Operations		X			
POW Cages		X		X	X
Security of Lines of Communication		X		X	X
Securing Key Terrain/River crossing	X	X		X	X
Reinforcement		X		X	X
Counter Penetration		X			
Urban Operations		X	X		
Infantry Assault/Attack				X	X

9.0 TOOLS, MODELS AND THEIR APPLICATION

Within the context of the study the majority of tools and methods used in the study were involved in data collection, data generation and collation.

Throughout the study an adapted version of the ACCES methodology (Lambert & Martel, 2002; ARI, 1995; Halpin, 1996) was used to gather the directed observations on exercise. Data were collected by observers using paper collection forms, followed by an end of shift time line debrief to establish a macro view of which processes had been triggered in response to the Exercise Main Events List. This was followed by a period of detailed transcription into the Observations Collection Program (OCP)[8]. The OCP was used to support the recording, sorting and collation of the observations. It was also used to enable post exercise statistical and quantitative analysis of the data and organised extraction of the qualitative SME statements. Following input of the data into the database the analysts could review the OCP data, attach comments where appropriate and issue new guidance for data collection at the commencement of the next shift. During the last two exercises the activities of individual resources (HQ Staff) were also recorded in the OCP and tracked on a HQ synchronisation matrix[9].

Due to budgetary constraints no specialist tool was procured to capture the HQ process definitions and conduct simulation. Instead use was made of a spreadsheet, a commercial business process simulation (SIMUL8™) and some simple database applications. The use of the spreadsheet to capture the diagrams and process descriptions was very successful as it enabled HQ Staff to annotate the diagrams and email comments without the problems usually experienced with expensive licensing arrangements in a dispersed study. The series of process analysis workshops used to clarify and consolidate the HQ Processes were most important, enabling a buy-in from the HQ Staff into their own processes and establishing an excellent working relationship with the Analytical team.

The wargaming method to derive statistics for the simulations utilised rules and algorithms recently used in the UK MOD for a variety of tactical studies. This wargame method was simply used to produce a realistic operational tempo and combat resolution. The specialist skills to run the manual game were contracted into the team for the duration of the wargames. During the wargames, the tactical situations were recorded and presented to the HQ Staff using an existing common operational picture capability[9] at no additional cost. The use of a HQ team-in-the-loop to derive the decision making for input back into the game and to identify the triggering of processes was most successful. It also had the additional benefit of illustrating to the HQ Staff the inter-relationships between their own functional area processes. Data on the HQ Processes were recorded using a simple database and the HQ synchronisation matrix[9].

In summary therefore, the tools in this study were used to collect data from exercises, workshops and wargames. Where models were used they were either already in existence and validated (the wargaming rules and method) or specially developed to the level of detail required for the study (e.g. the HQ process simulation). None of the outputs of any of these methods were singularly used to provide the definitive evaluation, but rather they were used collectively.

10.0 DATA

As already stated the primary data sources for the evaluation were the FTX and CPX of AMF(L). The use of such events as a means of conducting the C2 assessment had many drawbacks and was well known to the Analytical Team from the outset of the study:

a) Each exercise produced only one data point (one set of values for scenario/types of operations involved/tempo/etc.).

b) The training objectives of an exercise often conflicted with the requirements and expectations of the experiment. The artificial characteristics of an exercise, which are essential to meet training

[8] The OCP was provided to the CDE Analytical Team by HQ SACLANT Programs & Research Branch (HC-53). It was specially adapted by NC3A for the IRTF(L) data collection effort.

[9] The THISTLE environment, provided by Microprocessor Applications Group, Cranfield University, Cranfield, Bedford, UK.

objectives, may be damaging to the experimentation value. For example, training objectives often require unrealistic adjustments in operational tempo.

c) Training exercises violate the requirements of experimentation. Typically, from exercise to exercise, too many variables change simultaneously, making the association of cause and effect difficult to identify.

d) Training exercises are usually of short duration. They do not enable observation of sustained operations (where real C2 problems begin to build up). Additionally, there is no guarantee that the peak levels of work in HQ functional areas or staff processes, are reached.

e) Equipment, personnel and subordinate unit unavailability may force the introduction of further artificialities. This was certainly true for the AMF(L) exercises.

Despite the above points, the use of exercises did force a holistic look at the problem and allowed interactions between processes, equipment and personnel to be investigated. In addition the relative impact of training levels, augmentees (CE), differing national doctrines, and scenario conditions could also be observed. These were all interactions that would have been impossible to create in a laboratory setting or reliably represent within a computer simulation.

The use of Subject Matter Experts as sources of data was an important feature of this study. Many teams and individuals acted in the capacity of data generation SMEs:

a) The military observers used on exercise to identify and record HQ process data, gather statistics and to make professional observations on the effectiveness and accuracy of the implementation of the C2 Concept.

b) The HQ Staff in reviewing and amending the HQ Processes, followed by the production of the HQ SOPs.

c) The military staff supporting the CDE Analytical Team in helping identify the scenario specific and a-specific triggers within the simulation.

d) The military staff supporting the CDE Analytical Team in generating the scenarios for the wargames.

e) The wargame analyst in helping generate a realistic operational tempo and combat resolution.

f) The HQ Staff acting as a “team-in-the-loop” in the wargame, in helping identify the processes triggered in response to the vignettes presented.

g) The historical and military analysts in helping identify the operational tempo from the Falklands Land Campaign.

h) The command and human factors consultants, used to review the findings of the exercises.

i) The military observers used in the final exercises to monitor the areas of concern as identified by the simulation and the compliance of the HQ staff with the SOPs.

j) The military observers used to assess the timeliness and quality of the HQ products.

11.0 RISK AND UNCERTAINTY

Unfortunately the solution strategy and its implementation suffered from several limitations. The main methodological limitations were:

a) A complete coverage of the potential mission spectrum for IRTF(L) can not be claimed. However, the discrete point assessments conducted should provide a sufficient insight to the validity of the IRTF(L) C2 concept.

b) Only the C2 sub-concept of the IRTF(L) concept was examined. Possible interactions between the C2 sub-concept and the other parts should be taken into account when the study results are used. For example, enhancements in the IRTF(L) force pool may (will) change the nature and frequency of the occurrence of HQ processes, with an inevitable impact on this study outcomes.

c) This study was exercise-centric. Although augmented by other approaches most of the data used throughout this study originated from the exercises. Exercise artificialities naturally constrain the validity of the study outcomes.

d) During the exercises the IRTF(L) typically had two TGs in its structure. The full complement was not tested in the field. The simulation and wargames were therefore the only instances where the full concept of three TGs could be observed.

e) Experimentation of the C2 Concept and its implementation were conducted while the concept was still evolving. Consequently the results of this study can only reflect the assessment of the concept in one stage during evolution (although this was a stable and practical stage).

f) Only processes relating to J2, J3, J5, Offensive Support and Engineers were modelled. Other functional areas (i.e.. J1, J4, J6 and J9) were excluded from the assessment[10]. When the necessary sub-C2-concepts are developed and implemented they may subsequently influence the outcomes of this study.

These limitations can be summarised by what is known in the COBP as an "uncertainty of focus" (i.e. whether the assessment covers all of the important factors and issues). Due to these limitations, the results of this experiment could not be regarded as being totally authoritative or exhaustive. However, they were the best achievable results given the time and resource constraints. The project sponsor and stakeholders were kept aware of these uncertainty issues.

The limitations and uncertainties associated with this evaluation were fully communicated with the final study results to the project sponsor, the stakeholders and decision makers.

12.0 PRODUCTS

Throughout the project the Analytical Team continuously published its findings. This commenced with the CDE white paper and initial experimentation plan (SHAPE PRL, Dec 1999; NC3A Feb 2001). During the exercises the Analytical Team formally reported their findings to the Project sponsor and stakeholders in exercise reports (NC3A, May 2000, Oct 2000, Nov 2000, Mar 2001, Sep 2001, Dec 2001). The results of every workshop were documented and archived for possible future reference. All data collected were also archived and stored centrally for access by all members of the Analytical Team. Prior and during each

[10] The C2 sub-concepts relating to these areas were not developed at the time of data capture – and were not central to the cross functional processes considered.

exercise all process diagrams, SOPs and HQ layouts etc were also made available over the NATO WAN (CRONOS) for the familiarisation of observers and HQ Staff. A final report (NC3A, 19 Dec 2001) and methodology reports (Candan & Lambert, 2002; Lambert & Martel 2002; Lambert 2002) have also been produced.

Once the solution strategy was clear, the Analytical Team wished to have the method peer reviewed. This was however, not possible to arrange formally. The NATO RTO SAS026 working group however kindly allowed the project method to be informally presented to them and gave some valuable advice.

13.0 CONCLUSIONS

13.1 IRTF(L)

The experimentation conducted to evaluate the IRTF(L) C2 concept did not detect any fundamental flaws in the concept. It was assessed to be doctrinally sound and practical.

It was assessed that the C2 Concept is well suited to an infantry formation in warfighting (i.e. both CRO and high intensity Article 5). The concept however has not been assessed for its applicability to other types of formation.

Many problems however, were encountered with respect to the actual implementation of the C2 Concept. The single most important of these was the influence of the HQ manning regime on the quality of the HQ's work. In particular the high proportion of CE (augmentation) staff within the HQ.

What was fielded was the foundation of an operational HQ. There were a few systemic issues that need to be addressed to make it work to the satisfaction of the customers of its processes and many improvements to make it efficient and therefore operational.

All recommendations to enable the C2 concept that were listed at the end of the experimentation were practical and possible, given collective will, commitment, resources and money.

13.2 COBP

As already stated the COBP was used from the outset of the project. The key utility of the COBP to this project were:

a) To assist the Analytical Team to consider the C2 Concept in as wide a context as possible and also to look at the problem holistically – as per the NATO definition of C2 (organisation, processes, procedures and systems).

b) To continually try and articulate the problem and recognise the requirement to refine the solution strategy in response to the problem formulation.

c) To remain aware of the limitations of the solution strategy, and the impact of this on the results.

The COBP lessons learned for the Analytical Team were:

a) To be much more proactive at the start of a C2 study in rejecting methods (solution strategies) that are forced onto a study (such as the use of training exercises) before the initial problem formulation stage has been completed (or even started!).

b) To actively question any arbitrary deadlines set on a study – that (as in the case of IRTF(L)) will reduce the possibilities for experimentation and the number of scenarios explored.

13.3 General Lessons

Never again to be involved in an experimentation on an operational HQ – unless the operational responsibilities of that HQ are reduced to allow experimentation.

To question the wisdom of "big-bang" approaches to organisational change and or the introduction of new technology, as these will always produce a sub-optimal solution. The preferred solution strategy of the Analytical Team was to have had a planned methodical evaluated "directed evolution" of the concept. In this, each functional area and cross functional process would have been evolved through a series of "team-in-the-loop" experiments, culminating in a series of full exercises (rather than beginning with them). The imposition of the rapid simultaneous HQ wide evolution that was curtailed before maturity meant that the trace-ability and influence of the different variables could not be properly established and quantified. In essence the Analytical Team was left to evaluate a one single possible working version of the C2 Concept – rather than gaining a full understanding of the factors at work and helping establish an optimum implementation.

14.0 REFERENCES

ARI, (April 1995), "The Army Command and Control Evaluation System – Documentation", Research Product 95-09, Fort Leavenworth Unit – Manpower and Personnel Research Division, US Army Research Institute for the Behavioral and Social Sciences, Forwarded by Evidence Based Research Inc.

Candan, U. and Lambert, N.J., (to be published), "Methods used in the Analysis and Evaluation of the Immediate Reaction Task Force (Land) Command and Control Concept", NATO C3 Agency, Ref: TN 897.

DERA, (August 1999), "Guide to Best Practice (COBP) in C2 Assessment, UK Defence Evaluation and Research Agency.

Halpin, S.M., (June 1996), "The Army Command and Control Evaluation System", Research Product 96-04, Fort Leavenworth Unit, US Army Research Institute for the Behavioral and Social Sciences.

Lambert, N.J. and Martel, S., (to be published), "Immediate Reaction Task Force (Land) Command and Control Concept: Process Analysis and Simulation", NATO C3 Agency, Ref: TN 895.

Lambert, N.J., (to be published), "Immediate Reaction Task Force (Land) Command and Control Concept: Wargames and Historical Analysis", NATO C3 Agency, Ref: TN 896.

NATO, (2001), Article 5 of the North Atlantic Treaty, "NATO Handbook 2001", page 528, ISBN 92-845-0146-6 or http://www.nato.int.

NATO MC, (April 1970), "NATO Military Committee – General Directive for Allied Command Europe Mobile Force", MC137(final).

NATO MC, (November 1996), "NATO Military Committee – Annex B to MC Guidance for Defence Planning", MC-299/5.

NC3A, (29 February 2000), "NATO Concept Development & Experimentation (CDE) Experimentation Plan – Immediate Reaction Task Force (Land) Command and Control Concept", NATO C3 Agency, Ref. WP:PL/52/2000.

NC3A, (26 May 2000), "NATO Concept Development & Experimentation (CDE): Observations on Exercise ADVENTURE EXPRESS 2000", NATO C3 Agency, Ref. WP:PL/53/2000, Limited Distribution.

NC3A, (09 October 2000), "NATO Concept Development & Experimentation (CDE): Observations on Exercise ACTIVE IMPROVEMENT 2000", NATO C3 Agency, Ref. WP:PL/54/2000, Limited Distribution.

NC3A, (17 November 2000), "NATO Concept Development & Experimentation (CDE): Observations on Exercise ADVENTURE EXCHANGE 2000", NATO C3 Agency, Ref. WP:PL/55/2000.

NC3A, (23 March 2001), "NATO Concept Development & Experimentation (CDE): Observations on the IRTF(L) Computer Aided Exercise 2000", NATO C3 Agency, Ref. WP:PL/56/2001.

NC3A, (September 2001), "NATO Concept Development & Experimentation (CDE): Observations on the IRTF(L) STAFF EXERCISE 2001", NATO C3 Agency, Ref. WP:PL/57/2001.

NC3A, (11 December 2001), "NATO Concept Development & Experimentation (CDE): Observations on Exercise ADVENTURE EXCHANGE 2001", NATO C3 Agency, Ref. WP:PX/60/2001.

NC3A, (19 December 2001), "Evaluation of the IRTF(L) C2 Concept: Final Report", NATO C3 Agency, Ref. WP:PX/61/2001.

SACLANT, (23 March 1999), "Study on the Feasibility of Adapting A Process of Concept Development and Combined Experimentation Within NATO", SACLANT IMSM-276-99.

SHAPE PRL, (23 December 1999), "CDE White Paper: Immediate Reaction Task Force (Land) Command and Control, Experimentation Strategy", 11023-05-23/SHPRL/99.

SHAPE PRX, (12 May 1999), "Concept Paper: Immediate Reaction Task Force (Land) – A Complete Utility", 2100/SHPRX/01/99.

Spacie, K., Storr, J. and Waddell G., (to be published), "Immediate Reaction Task Force (Land) Command and Control Concept", Reports of Consultants, NATO C3 Agency, Ref: Consultant Report 140.

RTO, (March 1999), "Code of Best Practice (COBP) on the Assessment of C2", NATO Research Technology Organisation, TN 9 AC/323(SAS)TP/4.

15.0 LIST OF ACRONYMS

ACE	Allied Command Europe
AD	Air Defence
AMF(L)	ACE Mobile Force (Land)
AOR	Area of Responsibility

ARTY	Artillery
BMS	Battle Management System
C2	Command and Control
CAX	Computer Assisted Exercise
CDE	Concept Development and Experimentation
CE	Crisis Establishment
CIS	Command Information Systems
COBP	NATO Code Of Best Practice for C2 Assessment
COM	Commander
COS	Chief of Staff
CP	Command Post
CPX	Command Post Exercise
CRO	Crisis Response Operations
CS	Combat Support
CSS	Combat Service Support
DCI	Defence Capabilities Initiative
DCOS	Deputy Chief of Staff
DERA	Defence Evaluation and Research Agency (UK)
Div	Division
DSTL	The Defence Science and Technology Laboratory (UK) (one of the two successors to DERA)
ENG	Engineer
EW	Electronic Warfare
FHU	Force Helicopter Unit
FTX	Field Training Exercise
HQ	Headquarters
IRTF(L)	Immediate Reaction Task Force (Land)
ISIS	Royal Netherlands Army Integrated Staff Information System
JFCOM	US Joint Forces Command
JOC	Joint Operations Centre
LOC	Line of Communication
MC	The NATO Military Committee
MEL	Mail Events List (exercises)
MND(C)	Multinational Division (Centre)

MoCE	Measure of C2 Effectiveness
MOD	Ministry Of Defence
MoE	Measure of Effectiveness
MoM	Measure of Merit
MoP	Measure of Performance
NC3A	NATO Consultation Command and Control Agency
NTM	Notice to Move
OPFOR	Opposing Force (exercises)
PE	Peace Establishment
RISTA	Reconnaissance, Intelligence, Surveillance and Target Acquisition
RTO	NATO Research and Technology Organisation
SACLANT	Supreme Allied Commander Atlantic
SACEUR	Supreme Allied Commander Europe
SATCOM	Satellite Communications
SC	Strategic Command (as in Bi-SC – i.e. SACLANT and SHAPE)
SHAPE	Supreme HQ Allied Powers Europe
SIG	Signals
SME	Subject Matter Expert
SOP	Standard Operating Procedures
STAFFEX	Staff Exercise
TG	Task Group
TMS	Tactical Messaging System
TOC	Tactical Operations Centre
VNC	Voluntary National Contributions
WWII	World War II

AUTHOR BIOGRAPHY

Dr Umit Candan received his BSc and MSc degrees in Mechanical Engineering from the Technical University of Istanbul, and his Ph D in Operations Research from the Istanbul University. He worked as an associate professor in the Business Administration Faculty of the Istanbul University, lecturing and conducting research in Production Management, Operations Research and Quality Control between 1968-1981. At the same time he conducted several industry-sponsored studies in Master plan development for different industrial sectors, the re-organisation of State-owned enterprises, location selection for industrial complexes with multiple production sites and balance of production lines. Dr Candan joined the Operation Research Division of the SHAPE Technical Centre as a Scientist (later to become the NATO C3 Agency) in 1981. He participated in and conducted several studies for SHAPE using operations research approaches to assess military concepts, force requirements and courses of actions at strategic, operational and tactical levels. He is currently the Chief of the Architectures and C3I Analyses Branch in the Operations Research and Functional Services Division at the NATO Consultation Command and Control Agency in The Hague in The Netherlands.

Mr Nicholas Lambert is a graduate of the University of Wales (BSc Hons Environmental Biology) and Royal Military College of Science (Post Grad Diploma in Military OR). He has worked as an Operational Analyst on a wide variety of military tasks for UK MOD from 1987 to 1999. During this time (1994 to 1999) he was assigned to the Operational Analysis Branch at HQ Allied Command Europe Rapid Reaction Corps (ARRC), which included a 10-month deployment (1995/1996) to Bosnia and Herzegovina as part of the NATO Implementation Force (IFOR). Since 1999 he has worked on Land and Joint C2 issues in the Architectures and C3I Analyses Branch in the Operations Research and Functional Services Division at the NATO Consultation Command and Control Agency in The Hague in The Netherlands.

Analysis of Metrics Utilized in U.S. Joint Experimentation of Future C2 Concepts

RADM Gary Wheatley USN (Ret.)
Evidence Based Research, Inc.
1595 Spring Hill Road Suite 250
Vienna, Virginia 22182-2216
USA
[1] 703-893-6800
wheatley@ebrinc.com

ABSTRACT

The U.S. Joint Forces Command has been charged to lead the transformation of the U.S. Armed Forces through development and experimentation of new command and control concepts. In particular the Knowledge-C2 Working Group of the Concepts Division has focused on four related concepts:

- *Adaptive Joint Command and Control (AJC2)*
- *Common Relevant Operational Picture (CROP), and the Collaborative Information Environment (CIE)*
- *Joint Interactive Planning (JIP)*
- *Multinational Operations (MNOPS)*

This paper discusses these Knowledge-C2 concepts and related experiments in the U.S. JFCOM experimental campaign. It then reports on the Unified Vision 2001 Experiment (UV01) results showing how the HEAT metrics were used to develop analyses baselines and quantitative results. Finally it discusses the future of the experimental campaign and events.

Key Words*: C2, Metrics, Experimentation.*

1.0 INTRODUCTION

As the U.S. Joint Forces Command pursues its mission of transforming the U.S. Armed Forces, it has embarked on an experimental campaign that is designed to test new and innovative concepts for transformation. The current integrating, or over-aching concept is Rapid Decisive Operations (RDO), a concept to achieve rapid victory by attacking the coherence of an enemy's ability to fight. It involves the synchronous application of the full range of national capabilities in timely and direct Effects-Based Operations (EBO). It employs asymmetric advantages in the knowledge, precision, and mobility of the Joint Force against an adversary's critical functions to create maximum shock. Supporting RDO and EBO are several Knowledge and Command and Control (K-C2) concepts vital to RDO success. These K-C2 concepts include:

- Adaptive Joint Command and Control (AJC2)

Paper presented at the RTO SAS Symposium on "Analysis of the Military Effectiveness of Future C2 Concepts and Systems", held at NC3A, The Hague, The Netherlands, 23-25 April 2002, and published in RTO-MP-117.

- Common Relevant Operational Picture (CROP), and the Collaborative Information Environment (CIE)
- Joint Interactive Planning (JIP)
- Multinational Operations (MNOPS)

Figure 1 shows how these and other related concepts support RDO in the context of a Small Scale Contingency (SSC).

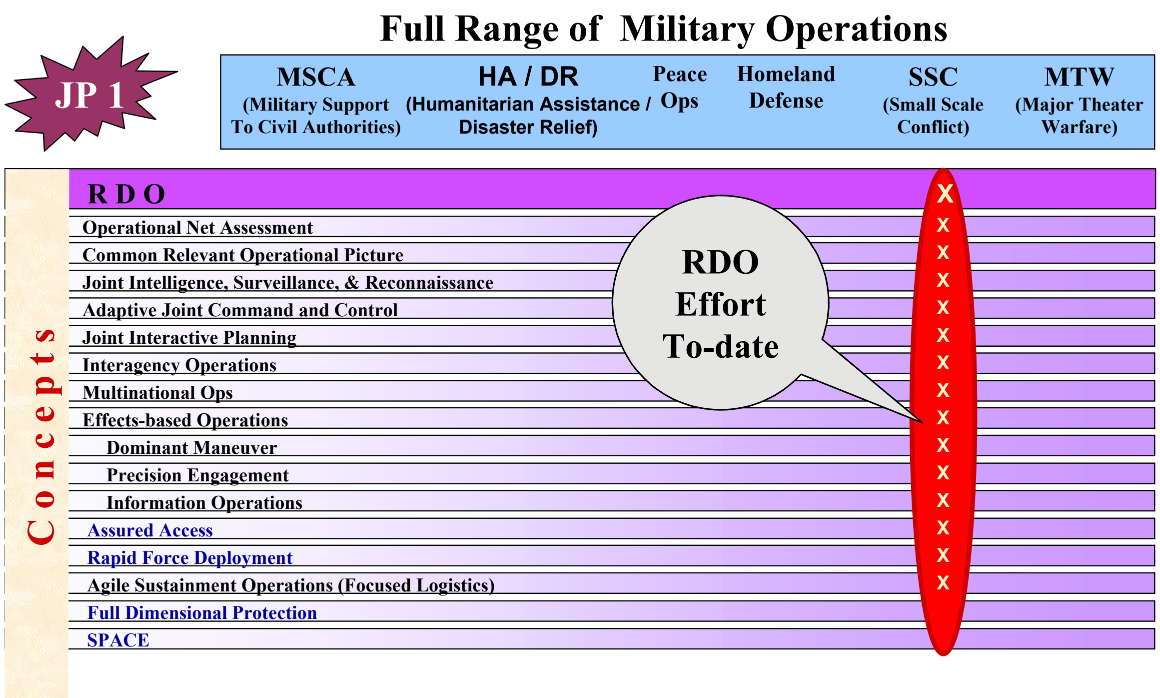

Figure 1: A View of the RDO Concept Family.

This paper focuses on selected Knowledge-C2 concepts and related experiments in the U.S. JFCOM experimental campaign. It then reports on the UV 01 experiment assessment results. In particular it discusses the Headquarters Effectiveness Assessment Tool (HEAT) metrics used to develop analyses baselines and quantitative results. Finally it discusses the future of the experimental campaign and related events.

2.0 THE KNOWLEDGE-COMMAND AND CONTROL CONCEPTS

2.1 Adaptive Joint Command and Control (AJC2)

RDO require more responsive and coherent advanced planning and quicker use of capabilities than can be accomplished by ad hoc stand up of a JTF headquarters.

Currently, when a Joint Task Force (JTF) is established, the crisis often has already evolved or is close to involving combat operations or overt hostile action by the adversary. As crisis management passes from the CINC to a JTF Commander, the coherency of plans and in-process actions may be lost. The new JTF commander must establish situational awareness, create a team, and establish processes that have not been practiced with the new team. At the most critical time of a crisis, when small actions can make large differences in the outcome, the C2 is in danger of being the most dysfunctional. This is illustrated by the bottom line in Figure 2.

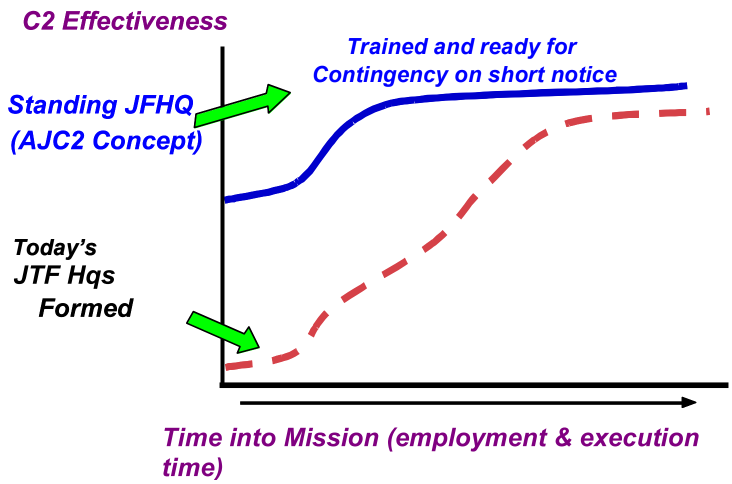

Figure 2: Improving JTF Readiness and Responsiveness.

Taking advantage of improvements in information technology, RDO AJC2 will use networks touching every part of the force and touching those that will provide information and direction to the force. These networks will be used before, during and after the crisis for training, planning, and communication. Practiced collaboration, habitual relationships, and sharing of situational understanding will enable greater coherence of C2 and more rapid and effective execution. The foundation for improved C2 will be a standing joint force command and control element in each CINC's headquarters (the top line in Figure 2). The C2 element will have the equipment, training and authority to become a backbone around which a JTF Commander's staff, when stood up, will operate. Rapidly deployable, and when augmented, this C2 element will be capable of operating alone for a small JTF contingency, or operating as part of a standing service operational headquarters designed as a JTF or the CINC's staff, depending on the size, scope and the expected duration of crisis response operations. This C2 element develops an Operational Net Assessment (ONA), which is an in-depth system of systems analysis of a region or potential adversary to identify and develop plans for a CINC priority set of selected missions. This process is shown in Figure 3.

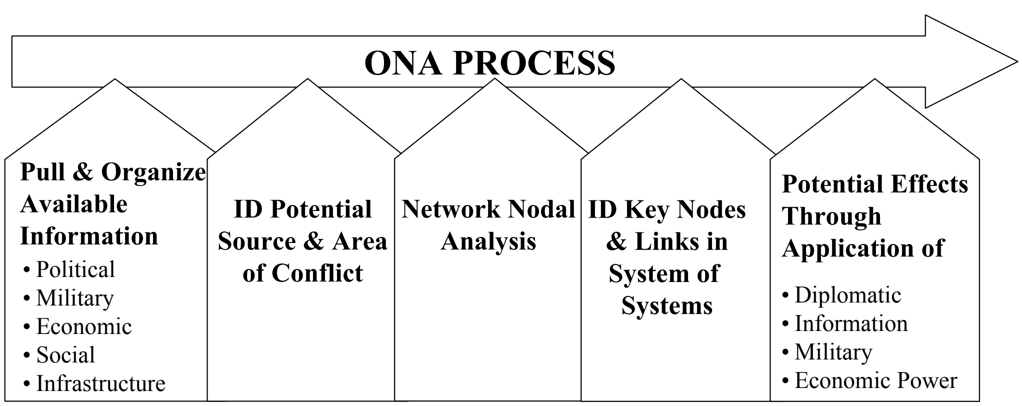

Figure 3: ONA Process Elements.

The coordinated application of national power is enabled by a refined interagency collaboration process that allows all partners to "inform and be informed by" the others. The C2 element works closely with the experimental interagency coordination cell (now designated as JX) on the CINC's staff. The value of reducing or eliminating the ad hoc nature of IAC response and political/military coordination will be a key element in successful RDO. Understanding that future operations will be conducted in a multinational environment, we will work with our partners to take advantage of the key assets, legitimacy, and political support they provide. The challenges of policy, dissimilar training, equipment, technology, doctrine, and language will be mitigated by peacetime engagement, training, and shared tools for planning.

In its day-to-day role the SJFHQ will develop the ONA and will have practiced those processes critical to crisis management and JTF execution. They will be prepared to respond with full situational awareness, practiced teamwork, and embedded collaborative processes and tools.

This should provide several key advantages:

- Possesses pre-crisis knowledge and understanding
- Becomes a high performance, well-trained team that understands the C2 processes and tools
- Takes advantage of habitual relationships formed with CINC's staff, subordinate commanders, and interagency and multinational participants. The SJFHQ would maintain important "reach-back" links to U.S. strategic planning and intelligence organizations, non-DoD agencies
- Conduct distributed C2 through multiple collaborative networks

Figure 4 illustrates one way the organization could function.

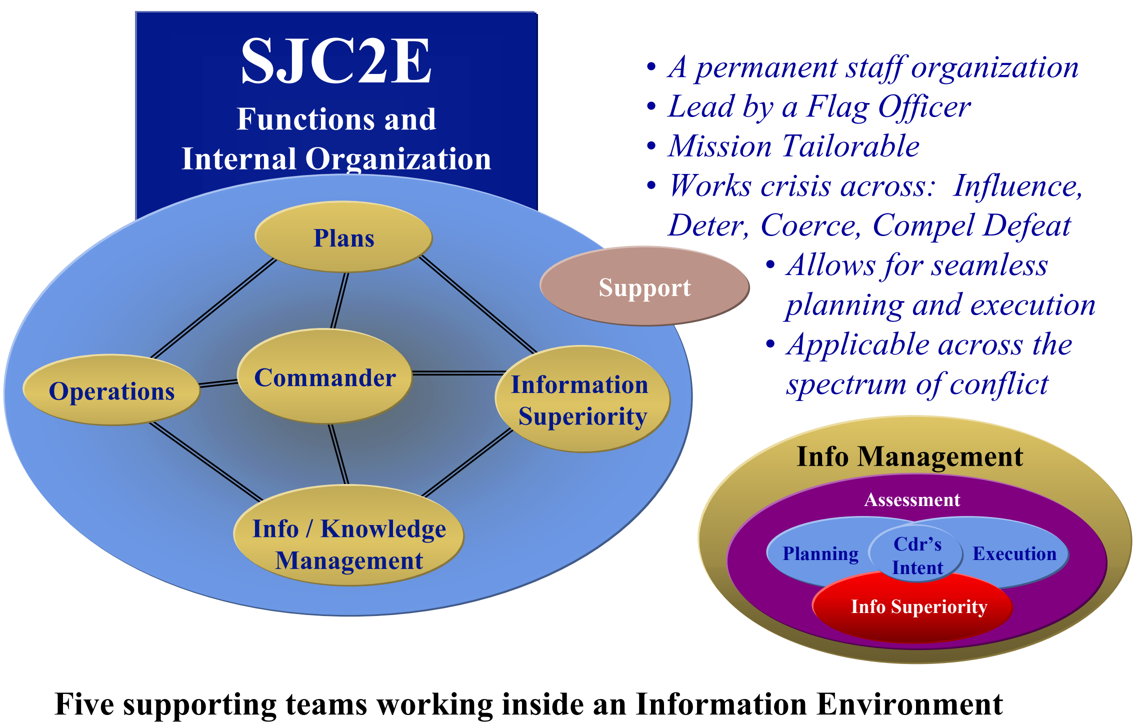

Figure 4: Alternative Command Arrangements for the JFHQ.

The AJC2 concept is *adaptive* in its actual composition and in the ways that the SJFHQ could transition from a peacetime posture to actual JTF operations. In the Millennium Challenge 2002 major experiment (MC 02) for example, the CINC designates a Service component headquarters as the JTF headquarters. This staff organizes itself as a JTF command staff around the knowledge based structure utilized by the SJFHQ.

2.2 Common Relevant Operational Picture (CROP)

The CROP is a "virtual information warehouse" that links to all the available information that the warfighters require. From this virtual warehouse, decision makers will tailor information displays that are relevant to their individual needs. The tailored displays generated from the common virtual warehouse will provide enhanced and shared Battlespace awareness at all levels. This is illustrated in Figure 5.

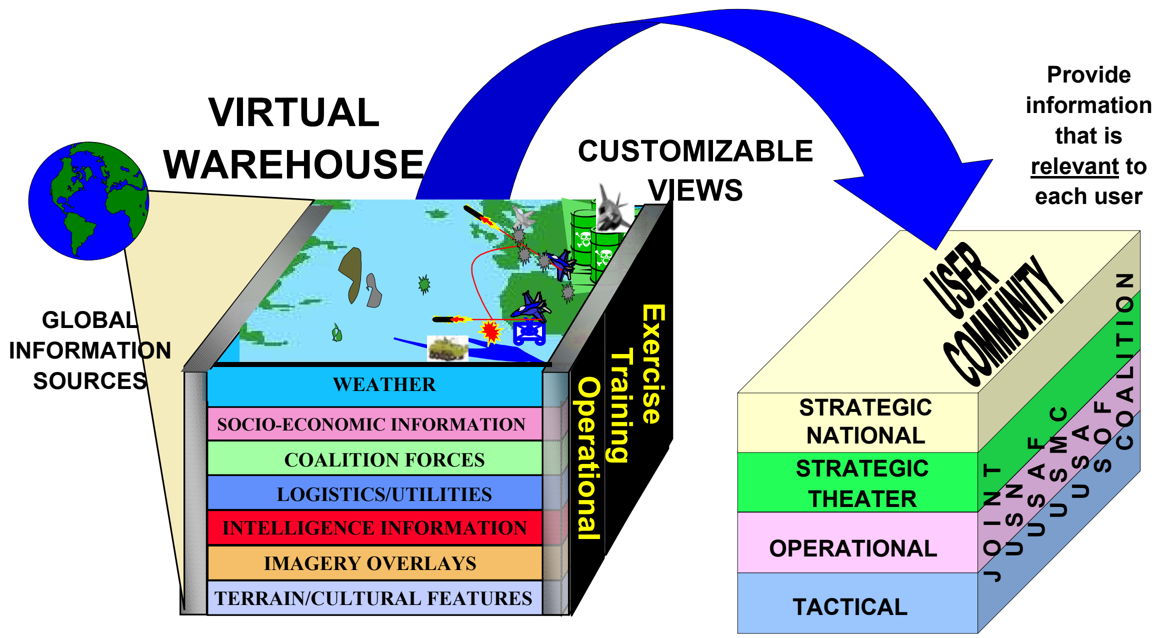

Figure 5: The Common Relevant Operational Picture.

The CROP concept focuses on the ability to access the virtual data/information warehouse enabling a presentation of timely, accurate, and relevant information that can be tailored to meet the requirements of the Joint Force Commander and every organization and individual operating in a joint environment. It includes and mutually supports non-DoD organizations, allied/coalition forces, and the existing common tactical pictures of the Services. The CROP's enabler, the Global Information Grid (GIG), interconnects associated processes and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, policy makers, and support personnel.

CROP is a key enabler to Adaptive Joint Command and Control, enhanced battle space awareness, and Joint Interactive Planning (JIP). The CROP is a functional concept that proposes the presentation of timely, fused, accurate, assured, and relevant information that can be tailored to meet the requirements of the joint force commander and the joint force. The goal is to find and present only that best set of relevant information the warfighting commander needs to make good decisions and to act. This is critical because a rapid decisive operation will be won through rapid, decisive actions.

The CROP concept is sufficiently robust and adaptable to accommodate the full range of exchange of information with non-DoD organizations (including governmental, international, and private) and coalition forces. It embraces and mutually supports the existing common tactical picture of the Services. The resultant presentation of information will be rapidly accessible by all approved users and will support the full range of military operations. Simply put, the CROP concept will attempt to define what information needs to be collected, how it should be processed (analysis and fusion), how it will be disseminated, and how it will be presented in the future.

2.3 Joint Interactive Planning (JIP)

The JIP concept embodies the notion of the use of information superiority to rapidly reach decision superiority. Previously, planning and execution have traditionally progressed in a distinct and sequential hierarchy. The JIP concept addresses a parallel planning process within a Collaborative Information Environment (CIE—note that the CROP and the JIP are both parts of the CIE). This environment utilizes distributed collaboration tools and virtual collaboration to facilitate simultaneity among CINC headquarters, Standing Joint Force Headquarters (SJFHQ), Joint Force staffs, the Service components, allies, and other organizations that are separated by time, organizational boundaries, and geography. The result is a common shared awareness, unity of effort, and better understanding of the commander's intent. The JIP concept leverages the latest technology advances in information and decision support systems and processes such as intelligent agents, which search secure, and open source databases to find information needed to support planning and execution. Support systems will extract, fuse, and translate the data to make it useful for decisionmakers. This is illustrated in Figure 6.

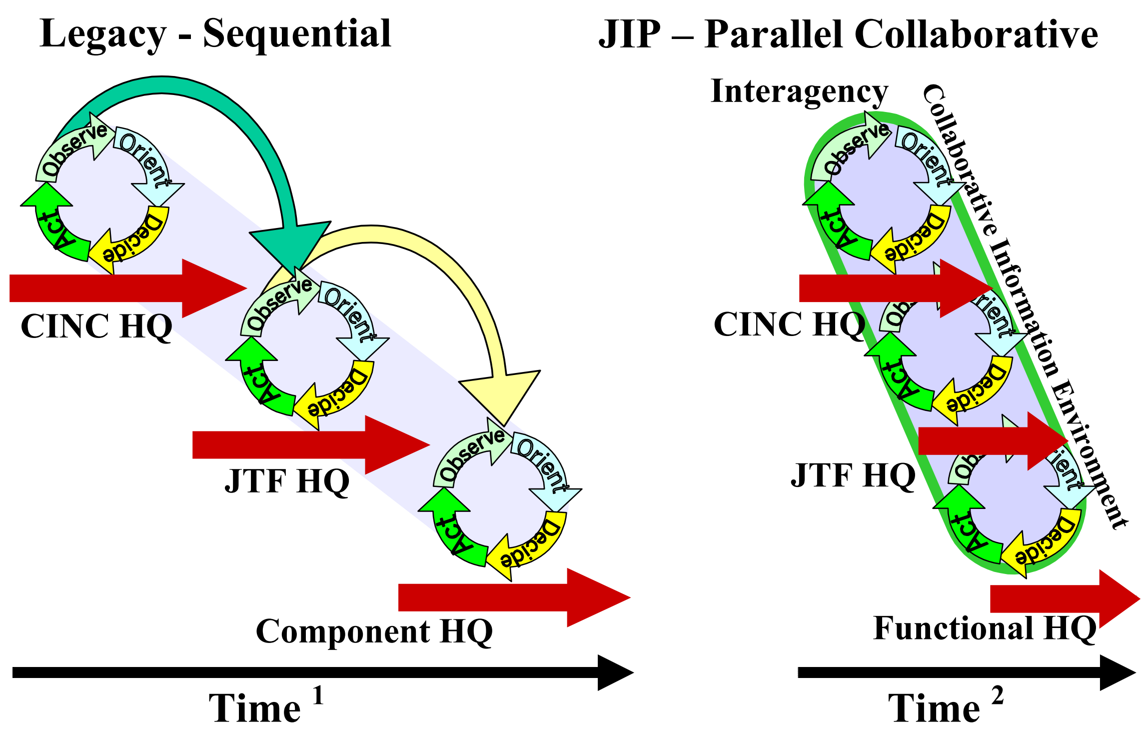

Figure 6: The Joint Interactive Planning Concept.

2.4 Multinational Operations (MNOPS)

Multinational Operations is not a unique concept in itself—rather it is the purposeful inclusion of multinational and coalition considerations and requirements in all the other supporting concepts. To facilitate MNOPS we have commenced a series of multinational Limited Objective Experiments (LOE) as depicted in Figure 7. Note that MNOPS will be included in the major experiment, Olympic Challenge 2004 (OC 04).

Figure 7: The Multinational LOE Relation to Olympic Challenge 2004.

The first MNOPS LOE focused on JIP by comparing an interactive planning process embodied in the JIP process with a more traditional sequential planning process. Subsequent LOE will focus on information sharing and collaboration.

3.0 THE U.S. JOINT FORCES COMMAND EXPERIMENTAL CAMPAIGN

Figure 8 depicts the J9 Experimental Campaign Plan. In the context of RDO it focuses along two distinct but related pathways – Millennium Pathway and Olympic Pathway. The Millennium Pathway concentrates on near-term transformation realizing the requirements to use weapons systems that are already in our arsenal or in production. The focus therefore is on how to conduct a Rapid Decisive Operation in this decade. The Olympic Pathway, in contrast, is an integrated set of experiments that will examine how the joint force can conduct RDO in the next decade. While the Millennium Pathway is centered on using today's major platforms more effectively through a greater degree of operational jointness, the Olympic Pathway will consider what capabilities we should develop and acquire as we replace today's systems over the next decade.

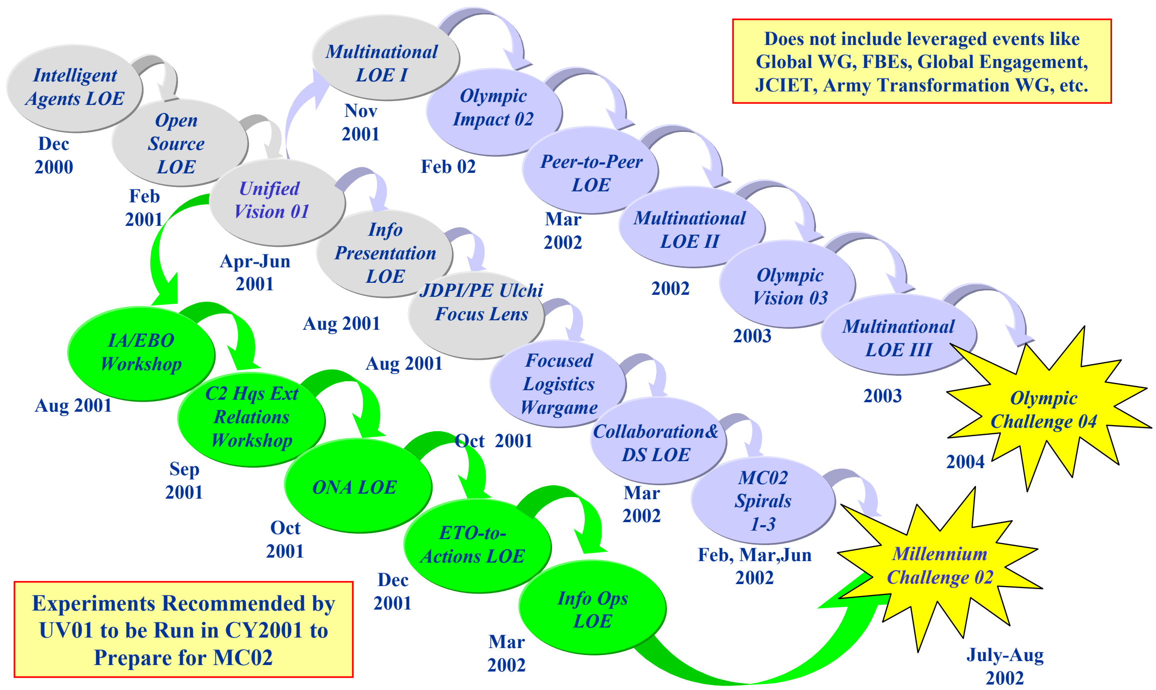

Figure 8: The J9 Experimental Campaign Plan.

Both pathways will utilize series of wargames and seminars to frame issues, simulations to integrate concepts and capabilities, and live, limited objective and major experiments. However since many of the Olympic Pathway capabilities to be assessed do not yet exist, the Olympic Pathway will rely more heavily on the use of simulations, surrogates, virtual portrayals, and prototypes. Lessons learned and finding developed from the Millennium Pathway will be incorporated into the Olympic event planning and execution.

4.0 EXPERIMENTAL ASSESSMENT METHODS

Experimental events prior to Unified Venture O1 (UV01) were assessed by subjective observation, participant surveys, and the traditional Army After Action Review (AAR) processes. UV01 was the first major experiment to be analyzed in detail and to assess objective data. The subjective data consisted of observations from retired General/Flag Officer Senior Concept Developers, senior members of the Interagency Community (to include two former U.S. Ambassadors), participants, and data collectors, as well as participant survey responses. Members of the JSJFCOM Joint Futures Lab analyzed the data and developed the experiment findings. In addition quantitative data was collected and analyzed through the HEAT methodology as described below. The complete analysis is contained in the UV01 Final Report available on the USJFCOM Web site.

4.1 The Headquarters Effectiveness Assessment Tool (HEAT)

The Headquarters Effectiveness Assessment Tool (HEAT) is a joint Command and Control (C2) assessment tool that has been applied to over 250 different headquarters involved in dozens of exercises, experiments, and real world operations. By defining the C2 system as an adaptive control system and separating C2 measures of effectiveness (MOE) from the supporting measures of performance (MOP), HEAT has proven to provide a robust capacity to both understand the quality of C2 processes and to diagnose the sources of C2 problems so they can be addressed effectively. Figure 9 illustrates the HEAT Cycle.

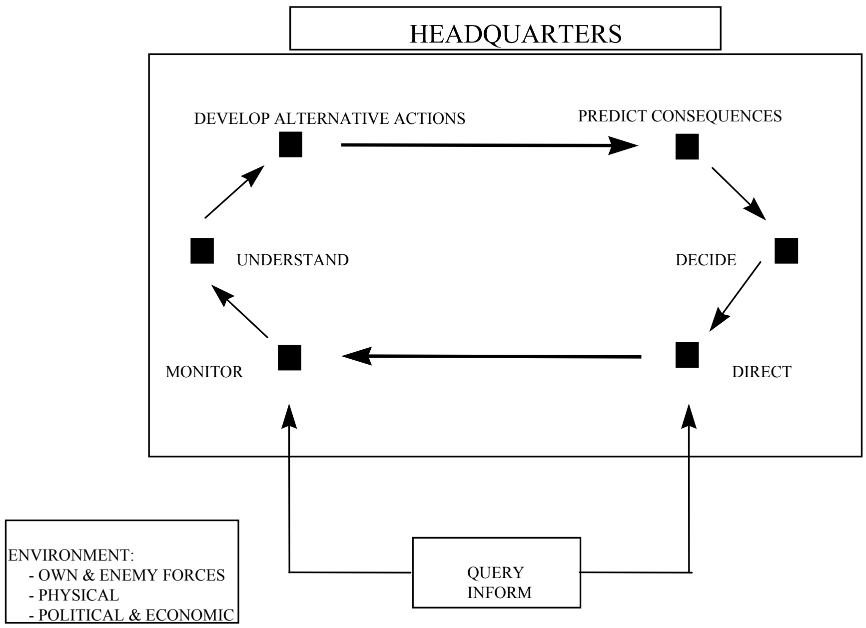

Figure 9: The HEAT Analytic Structure.

A headquarters operates in a complex environment that includes among other things, own and adversary forces, the physical environment, and all other relevant factors and players. By monitoring the environment, headquarters staffs achieve situational understanding from which they can develop courses of action (COA) and predict the consequences of these COA. The Commander then chooses a course of action and issues a directive, which in turn causes an effect on the environment that the headquarters monitors. While this description implies a cyclical operation, the impact of information technologies and collaboration tools enables many of the steps to be developed in parallel rather than sequentially.

HEAT metrics can be taken at any point in the cycle and, also measure the degree and effectiveness of collaboration. For example, in an experiment or exercise where there is an established ground truth known about the environment, HEAT can measure the quality of the monitoring process as a percent of ground truth (e.g., just how accurate is the headquarters' displays of own and enemy forces). In a similar vein, HEAT can measure the accuracy and quality of the understandings that the staff and commander derive from the monitoring (e.g., "the enemy is preparing to attack").

Because of the structure of the UV 01 experiment, HEAT metrics were not applicable at every point in the cycle. This was primarily due to daily scenario time jumps, and the fact that much of the experiment was heavily scripted to support experiment objectives (e.g., development of the Operation Net Assessment (ONA) and Effects Tasking Order (ETO). Accordingly the HEAT team focused analyses on understanding quality, decision cycle times, and collaboration effectiveness. The hypothesis was that: "A richly connected JTF Staff will develop and maintain high quality situational awareness (SA)." The metrics to support this hypothesis would be strong scores for understanding quality and frequent statements of "understandings."

4.2 Results: Understandings

An "understanding" is a situation assessment which can be thought of as a hypothesis or set of hypotheses dealing with past, current and future situations. These are scored as Correct (actual situation matches primary hypothesis), Not Incorrect (actual situation is included in contingencies), or Incorrect (actual situation is not considered). Figure 10 summarizes the results of 91 "understandings" observed, recorded, and scored in the experiment.

Time Period	Weighted % Correct	n
Week 1	93%	21
Week 2	86%	42
Week 3	69%	28
Total	83%	91

– Weight n = # Understandings scored
  - Correct = 1
  - Not Incorrect = .8
  - Incorrect = 0

- Decline of scores over time normal as OPTEMPO increases
- High scores during week 1 indicates employment of core JTF as part of CINC staff effective in that evidence of "learning curve" was not present
- Pre-scripted Red during week 3 reduced # of cases that could be scored

Figure 10: Understanding Quality.

The high percentage for weighted correct scores in Weeks 1 and 2 indicate that the standing JFHQ resident within the CINC staff promotes early effectiveness and significantly reduces the "learning curve" usually associated with a newly formed JTF. The decline noted during week 3 can be attributed to the increased OPTEMPO (3 separate execution vignettes) plus the fact that the execution events were all pre-scripted and played out in simulation. The primary focus of the staff during this period was to update the ETO. There was little focus placed on the actual, scripted execution.

The "understandings" results tabulated above, while useful in themselves are much more relevant when compared to a baseline. There were no direct baselines for this particular new innovative concept. However, since these comparisons are important and provide great value for data interpretation, the HEAT team utilized the deep store of previous HEAT data and derived two "Surrogate Baselines." These are presented in Figure 11.

Quality of Situational Awareness

Surrogate Baselines	Day 1	2	3	4	5	Overall	
Joint Command Exercise in the 1980s [1]	.52	.62	.52	.60	.65	.60	Median % Correct
US Army Divisions circa 1990 [2]	.74	.82	.84	.82	.82	.81	Average % Correct

UV01	Week 1	Week 2	Week 3	Overall	Weighted % Correct
	.93	.86	.69	.83	

Interpretation:

- UV01 appears to have achieved higher understanding quality than surrogate baselines
- Unlike the Surrogates, understanding quality in UV01 declines over time
  - Time pressure is greater in later stages of UV01
  - Goal for future experimentation should be stable high % correct
  - UV01 understandings cover full range of PMESI; Surrogates focused on military issues

1 - "HEAT and the Warrior Preparation Center", Defense Systems Inc., August 1985
2 - "Use of ACCES and JESS data to Support Analyses of the Relationship of Command Staff Performance and Battle Outcomes", Defense Systems Inc., July 1988.

Figure 11: Surrogate Understandings Baseline.

Two surrogate baselines were examined. The first was developed from Joint Command and Control Exercises conducted by various staffs in the 1980s. These were conducted over 5-day periods and show strong evidence of the "learning curve" effect. The second surrogate was derived from 10 Army Division level field exercises and shows a less pronounced learning curve and a significantly higher level of understanding quality. When experiment data are compared to these surrogates, an even higher level of understanding quality is noted, particularly during Weeks 1 and 2. The relevance of the Week 3 scores is viewed as qualitatively different than those for Weeks 1 and 2, because of the shift from effects based planning to the three separate execution events. In any case, the data support higher understanding quality in the experiment. It is also important to note that the surrogate baselines focused only on military issues while experiment understandings covered the full range of PMESI (political, military, economic, social, infrastructure) as shown in Figure 12. The data also point out that a goal for future experiments should be a stable high percentage of correct understandings to support Effects Based Operations (EBO).

PMESI Count - Percentage of Understandings for each category / % Correct

Time Period	P	M	E	S	I	n
Week 1	41% / .83	49% / .98	8% / 1.0	2% / -	0% / -	49
Week 2	32% / .88	53% / .84	7% / .80	3% / -	5% / -	81
Week 3	21% / .33	71% / .74	4% / -	4% / -	0% / -	48
Total	**32% / .79**	**55% / .84**	**7% / .90**	**3% / -**	**2% / -**	**178**

n = total number of Understandings recorded
"-" = none scored

- Large increase in percentage of military during execution (Week 3) phase
- Few understandings expressed regarding economic, social and infrastructure
- Increasing military percentage over time trades off with percentage correct over time
- Focus on military understandings suggests the presence of "tunnel vision" which would threaten PMESI analyses and Effects Based Operations

Figure 12: Understandings Across the PMESI Effects.

UV-01 explored new ground by its integrated focus on the effects of the total range of U.S. national power across the continuum of peacetime environmental shaping efforts, to disaster relief, to a small-scale military contingency. A large number (178) of understandings were achieved across the PMESI domains. Many of these understandings could not be scored (e.g., correct, not-incorrect, incorrect) because of the scripted nature of the experiment and the scenario time jumps. The data also show that the participants' focus was primarily on the military and political domains. As the scenario developed the "tunnel vision" phenomenon was observed as the participants focused more and more on military action, particularly in Week 3. This explains in good measure the low number of understandings in the economic, social and infrastructure domains. Nevertheless, successful EBO require a continuing focus on PMESI at the operational and strategic levels. This indicates a need to develop tools that will help the participants maintain focus across the PMESI spectrum and avoid tunnel vision.

Percentage of Understandings that considered past, present and future situations

Time Period	Past	Present	Future
Week 1	4%	54%	42%
Week 2	3%	48%	49%
Week 3	5%	53%	42%

- Less than half of Understandings considered the future
- Not ideal to support planning or Effects Based Operations

Time Horizon - amount of time considered in future Understandings

- Example: "After today, Red capability to deploy TBMs will be reduced" (24 hours)

- Mean future time horizon: 2.3 Days (game time)
- Median future time horizon: 2 Days (game time)

Conclusion: These time horizons are more appropriate for the tactical than the operational level

Figure 13: Understanding Time Horizons.

4.3 Time Horizons/Decision Cycle Times

Understanding time horizons are important because they indicate how far into the future the staff is projecting the implications of its planning and directives, as well as the possible impact of what is already past. In the experiment less than half of the understandings considered the impact of that understanding on future operations. The median future time horizon of only 2 days recorded in the experiment is more appropriate to the tactical level and much less so to the operational and strategic levels, and definitely not ideal to support EBO planning.

	Average Cycle Time (hours)	Median Cycle Time (hours)	n
Week 1	29	21.5/24.5	6
Week 2	27.5	23.5	3
Week 3	21	23	7
Overall	25.1	23/23.5	16

- Cycle times above represent real time
- Cycle times based on game time have little meaning due to time jumps between game days
- Doesn't account for events occurring during jumps
- Doesn't factor in overnight dead time

Conclusion: The Decision Cycle Times were stable across the experiment rather than shorter during the execution phase

Figure 14: Decision Cycle Times.

Decision cycle times are important indicators of staff efficiency, connectivity, and collaboration. The average and median times listed in Figure 14 tend to be artificially long because of the scripted game time jumps, and the overnight dead time. Nevertheless, the experiment cycle trends provide useful insights. While the average cycle times showed an expected compression, the median times did not, indicating that the cycle times were essentially stable across the experiment rather than shorter during execution events. Some cycle times were particularly long. Examples of long cycle times are provided in Figure 15.

- **Decision**
  - Required TMD defense of Green. First indication at 261545Feb, second when Green demands Patriots (171309Mar), TMD COA developed 011120Apr. Total 34 days (Game), 68 1/2 hours (Real)
- **Understanding**
  - At 010900APR (14 May-Real) CJTF states need to understand relationship between Red government and JTF-S. At 030900May (21 May-Real) relationship still not clear. Total 32 days (Game), 7 days (Real)
- Cycle times possibly could have been shortened had State been represented during initial planning sessions when these items were discussed

Figure 15: Long Decision Cycle Times.

These long decision cycle times are symptomatic of the need to enhance the participation of State and other relevant agencies in the experiment. The interagency process in effects based operations at the operational level is an evolving process and the experiment clearly demonstrated that there is much to learn if we are to fully exploit EBO in the context of Rapid Decisive Operations (RDO).

4.4 Collaboration

A rich collaboration environment is essential to support the RDO and EBO concepts. During the experiment there were 188 collaboration sessions documented. However, not every data element of each session was captured on the data collection sheets. This resulted in differing frequencies of responses/results for methods, tools used, and purposes of collaboration session. For example, data regarding collaboration purpose was recorded for 116 out of a total of 188 collaboration sessions because of incomplete information on the data collection forms. This was not because of data collection errors or omissions, but rather because the specific information (collaboration purpose in this example) was either not explicit or obvious, and the data collectors were trained to be unobtrusive to not interfere with the experiment.

The collaboration summaries shown in Figures 16 and 17 show interesting trends. The large amount of face-to-face collaboration in Weeks 1 and 2 as illustrated in Figure 16 is attributed to two key facts. First, the DCTS (Defense Collaborative Tool Set) was fragile and its capabilities built slowly over the first two weeks of the experiment. Second, as the participants' became more comfortable and familiar with the on-line tools, they found ways to use them more effectively (learning curve and cultural bias shift).

Method	Week 1	Week 2	Week 3
Face to Face	23 (50%)*	24 (57.1%)*	18 (32.7%)
On-Line	23 (50%)*	18 (42.8%)	37 (67.2%)*
Tools**			
Whiteboard	3 (10.3%)	5 (25.0%)	2 (4.8%)
File Sharing	13 (44.8%)*	13 (65.0%)*	3 (7.3%)
Chat	1 (3.0%)	0	8 (19.5%)
IVOX	Not Avail.	Not Avail.	12 (19.7%)*
E-Mail	0	0	5 (12.2%)
VTC	1 (3.0%)	2 (10.0%)	1 (2.4%)
Other	11 (37.9%)	0	10 (24.4%)
Not Recorded	22	24	20

- Frequency of face-to-face was consistent over first 2 weeks then declined in third week as online interactions increased

* Indicates most frequently occurring activities & tools used
** Reported collaboration sessions only

Figure 16: Collaboration Summary of Events (1 of 2).

	Week 1	Week 2	Week 3	Total
Collaboration Purpose				
Decision Making	1 (2.6%)	0	3 (6.1%)	4
Situation Awareness	5 (13.2%)	9 (31.0%)	16 (32.6%)*	30
Planning	28 (73.7%)*	19 (65.5%)*	22 (44.9%)*	69
Other	4 (10.5%)	1 (3.4%)	8 (16.3%)	13
Problems Reported				
Procedure	0	0	3 (23.1%)	3
Training	1 (16.7%)	0	0	1
System	4 (66.7%)	4 (80.01%)	10 (76.9%)	18
Personal	0	1 (20.0%)	0	1
Other	1 (16.7%)	0	0	1

- Planning Collaboration was most frequent, with SA 2nd most common
- Planning Collaboration Activities decreased over time, as Situation Awareness Collaboration Activities increased over time
- Observers did not focus on or report many problems; most were system problems

* indicates most frequently occurring activities

Figure 17: Collaboration Summary of Events (2 of 2).

Collaboration was most utilized during planning and for situational awareness. As the experiment focus shifted to execution during Week 3, situational awareness collaboration increased significantly. Problems reported with collaboration were mostly associated with the DCTS system, however the learning curve evidence also indicates that more, up-front training would have been valuable. Figure 18 shows some examples of how collaboration made significant differences for both planning and execution, and offers the insight that the collaborative environment is essential for rapid planning and execution.

Week 1 - COA #2 chosen by CINC within 23 minutes of COA alternatives being developed. Short cycle time possible because CINC represented in COA development process.

Week 3 - CINC disapproval of use of C-117s in assault operations. This became known to planners during ETO 1C development, enabling work-around using "chat" feature to be constructed during planning process—CINC was represented during planning collaboration process.

Week 3 - CINC representative notices that CPCM sites not incorporated in ETO 1B during planning.

Week 3 - Dynamic retasking of ISR assets to identify hostile intent of swarming boats accomplished in 15 minutes as a result of collaboration between SOF OPS, CINC JIC, JTG OPS Director, JSOTF.

Figure 18: Collaboration Helped Examples.

4.5 Summary

The hypothesis that "A richly connected JTF Staff will develop and maintain high quality situation awareness," was supported. When compared to surrogate baselines of both command post (CPX) and field (FTX) exercises, the experiment understanding quality was clearly better. This enhanced quality is particularly relevant given the experiment scripting and time jumps, which would tend to reduce understanding quality because of the lack of situational continuity. The absence of the learning curve effect is a strong indication that the core STFHQ concept is on the right track.

The collaborative environment and resulting collaboration are the links that provided the "rich staff connection." As the collaboration tools became more robust over the course of the experiment, and the JTF staff became more adept with the tools and more comfortable working in the collaboration environment, planning errors and decision cycle times were reduced. Collaborative planning started immediately while situational awareness collaboration developed over time. Further training and experience with the collaboration tools should further improve collaboration.

While the empirical data indicate that the time horizon was short of ideal, this may well be an artifact of the experimental design. Extensive, heavy scripting and time jumps caused the participants to be faced with a new situation every day. Under these conditions, it is difficult to achieve and maintain coherent time horizon continuity.

Likewise, the long decision cycle times observed were attributed to both the experiment design and the need for greater and better-integrated interagency involvement in the experiment. Effects Based Operations cannot achieve their potential through military actions alone. There must be strong linkage and involvement by the other relevant actors to maintain the effects focus and to avoid tunnel vision. Future experiments should emphasize interagency involvement in the EBO process.

5.0 THE ROAD AHEAD

While the terrorist attacks of September 11, 2001 have caused increased emphasis on homeland security, the U.S. Joint Forces Command is still fully committed to the transformation of the U.S. Armed Forces through Joint Experimentation. The Experimental Campaign Plan may receive some fine-tuning, however the basic goals and milestones will go forward as planned. Quantitative analysis utilizing HEAT will remain an integral part of the assessment methodology.

AUTHOR BIOGRAPHY

Rear Admiral Gary Wheatley USN (Ret.) is a Program Manager at Evidence Based Research, Inc. He is a former Navy Pilot and Aircraft Carrier Commanding Officer. Since leaving active duty he has specialized in advanced technologies and command and control research.

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Attrition in Network Centric Warfare

John Erbetta
Defence Science and Technology Laboratory
Malvern Technology Centre, St Andrews Road
Malvern, Worcestershire WR14 3PS
UNITED KINGDOM
[44] 1684 771186

jherbetta@dstl.gov.uk

ABSTRACT

Network Centric Warfare (NCW) is concerned with exploiting information to maximise combat power. Integration of C2 systems is able to increase military effectiveness, whether in manoeuvre, engagement, logistics or protection. However this increases the potential length of the 'electronic' chain from 'sensor to shooter'. This paper has its focus on the issue that battle damage and force attrition (both equipment and human) occur in real conflict. The hypothesis is that at some point this may result in decreased force effectiveness rather than increased advantage. Information warfare means that positive attacks on systems themselves compound the problem. Emerging technologies applicable to NCW as a force multiplier need to be recognised as a counter to the impediments to progress that are recognised as inhibitors in the development of NCW. The impact of battle damage, attrition and cyber attack is addressed, as well as system security and the associated human factors of authority and responsibility. Options to minimise these vulnerabilities are postulated. The development of distributed systems and potential of using arbitration in decision making is viewed as one option to minimise the impact of performance on C2 effectiveness. The paper also recognises that whilst dominance (in its widest sense) is the ambition of symmetric warfare, this cannot be guaranteed whilst, in the asymmetric case, structures can be undermined by relatively unsophisticated attack. In particular the purpose is to underline the fact that implementations need to ensure that attrition results in 'graceful', rather than catastrophic, degradation. At the extreme end of the C2 performance spectrum the question must be asked how far can degraded C2 performance threaten force effectiveness. Assessment at this level is difficult and real answers are only likely to come from real life exercise that study the degree of reliance on C2 effectiveness during battle. The output will indicate the steps that need to be taken.

***Key Words**: Attrition, Network Centric Warfare.*

1.0 INTRODUCTION

1.1 Purpose

The purpose of this paper is to review the impact of attrition on Network Centric organisations faced with the attentions of a competent, knowledgeable adversary. It recognises that 'network centricity' is a growing feature of all organisations, the military not excepted. The extent and timeframes can be debated but already there is increasing integration of systems. It is considered that this trend will continue, possibly up to the point where all command and control systems are fully integrated with sensor and weapon systems. The burden of this paper is to underline that the entire system then becomes an entity which adversaries will target in what they regard as the most effective way.

Paper presented at the RTO SAS Symposium on "Analysis of the Military Effectiveness of Future C2 Concepts and Systems", held at NC3A, The Hague, The Netherlands, 23-25 April 2002, and published in RTO-MP-117.

The term adversary is used to cover the entire range of opponents from conventional forces, through 'conventional asymmetry' and terrorism to civil protest groups.

1.2 Network Centric Warfare

Network Centric Warfare [1] has been most clearly articulated in the open source material through the US Department of Defense publications. These papers have been used as the base for this discussion, whilst recognising that other nations have differing definitions and terms. Similar concepts are in development in non-military circles, indeed, NCW has been equated to e-business.

This paper is concerned with general principles in the integration of military systems (C2, sensors etc.). The US Department of Defense, through its C4ISR research programme has, in the unclassified literature, been most articulate in expressing the concept as Network Centric Warfare (NCW), defined as

"The tenets of NCW are:

- A robustly networked force improves information sharing
- Information sharing enhances the quality of information and shared situation awareness
- Shared situational awareness enables collaboration and self-synchronisation, and enhances sustainability and speed of command
- These, in turn, dramatically increase mission effectiveness

Within the concepts the impediments to progress are recognised and are summarised as including:

- Lack of secure, robust connectivity and interoperability
- Intolerance of disruptive innovation
- Lack of understanding of key aspects of human and organisational behaviours
- Lack of NCW-related technology investments"

(Source: NCW [1])

This paper is especially concerned with some of the latter issues. The basis is that we are steadily moving towards Network Centric concepts. Therefore we should clearly identify and assess the impact of specific attacks on the core of this new infrastructure. NCW can be analysed as a federation of systems. However a system that combines sensor to shooter capability is not simply a process but a battlespace platform in its own right. As such it will be a legitimate target for attack and its effectiveness will be measured not only by the way in which it performs (its fighting capability) but also on its defensive capability, its human resources and its damage control facilities.

In organisational terms, the impact of NCW is to move force structure towards a virtual organisation [2] effectively fragmenting traditional chains of command, and introducing clusters. Its impact on military organisation needs further work.

1.3 Purpose of Attack

The purpose of an attack is to deny key components within a weapon system to inhibit the OODA (Observe, Orient, Decide, Act) loop. Since a weapons system is a combination of one or more weapons, with all the related equipment, materials, services, personnel and means of delivery and deployment required for self-sufficiency, it follows that the NCW concept means that the planning and operational infrastructure must be included within that definition. Hence the NCW 'infrastructure' becomes as much a target as the sensors or weapon system.

It is this change, from Command and Control being a 'management' process to that of being part of an integrated weapon system, that means consideration of the impacts of specific attack should be considered in the evaluation of system of systems which have network centric attributes. Here one of the major issues is how to assign measures of merit. In particular a successful cyber attack is likely to be one that has not been anticipated. 'Sleeper' code (i.e. rogue software that is benign until triggered by time or an event) could have dramatic effects especially because the attack and its effects are separated by a time interval which could be months. Measures of merit do not exist in isolation and, for example, measuring the impact of C2 attrition needs to be mapped onto force effectiveness and related back to C2 effectiveness. If the wrong measure is used then it is conceivable that a major impact on C2 effectiveness could create a minor impact on force effectiveness whilst a 'minor' impact on C2 effectiveness would have a major impact on force effectiveness.

Robert Bunker [3] has written on the vulnerabilities of the Army After Next (AAN) to sophisticated cyber attack, one of the issues considered in this paper.

2.0 NATURE OF ATTRITION

2.1 Impact of Attrition

The word Attrition can be construed in a number of ways. Specifically any reduction in capability is included and in this is included battle damage, human casualties and cyber attack. The Shorter Oxford English Dictionary emphasises 'wearing or grinding down'. The burden of the paper is that evaluation must be made of the impact of this wearing away. For example, it should be possible to measure the impact of manpower attrition on C2 or force effectiveness and indeed create some relationship between the two. However if this is combined with equipment damage and cyber attack the impact on effectiveness at C2 and force levels is likely become more marked. The evaluation should not ignore such possibilities.

For the purposes of this paper 3 areas are considered at 3 levels:

- the levels are personnel, military sensor/command/weapon systems and infrastructure.
- the attacks will be against manpower, equipment and cyber targets.

Target \ area	Personnel	Systems	Infrastructure
Manpower	Primary Impact	Secondary Impact	Secondary Impact
Equipment		Primary Impact	Primary or Secondary Impact
Cyber	Secondary Impact	Primary Impact	Secondary Impact

A successful attack aimed at personnel will have a primary impact on force structure but is likely to have a secondary impact on systems and infrastructure, as support to these areas will depleted.

Successful attack on equipment will have not have a direct impact on personnel but may have an impact on infrastructure.

A successful cyber attack will primarily impact on systems but may well have a secondary impact on infrastructure and human (e.g. misinformation).

2.2 Manpower Attrition

Manpower attrition can be both temporary and permanent. The prospect of the use of chemical or biological weapons has potentially broader impact on network centric operations than in conventional operations. In modelling (or other form of assessment) manpower attrition in NCW it is important that all impacts are considered. Manpower has an impact on all four lower levels of Measures of Merit (see [4] Figure 5.1). The reason for this is that even the lowest level (Dimensional Parameters) such as the network 'wiring' is dependent on people.

2.3 Equipment Damage

Damage can be caused though direct or indirect attack (and indeed accidental damage should not be excluded). In the first place destruction of the nodes (or of essential supporting facilities e.g. electricity supplies) must be considered. This should be assessed on a physical basis (i.e. what components are situated in a particular area or building). Theoretical assessments may consider networks as separate entities but frequently they are co-sited with other elements from other networks.

The conventional measures such as quality of service and mean time to repair can be dramatically changed if there is significant, co-located damage (and it should be recognised, in evaluation, that network and human casualties may occur simultaneously). This, in network centric operations, could have significant impact on force effectiveness.

Networks are becoming increasingly sophisticated. The move away from conventional 'wirebased' systems to wireless and complex photonic systems means that systems performance in extreme circumstances becomes uncertain. Systems being installed and being planned have significant, in built, redundancy. However their performance under stress is complex. In significant incidents reduction in capacity results in an increase of traffic. Again the determination of appropriate measures of merit needs careful consideration.

3.0 THE ISSUE

3.1 NCW Provides Competitive Advantage

The objective of warfare is to achieve dominance. Reliable Command and Control systems, used in the decision making process, speeds decision making. As more systems are integrated the improvement in the speed and accuracy of the command process increases. In the competitive environment that is today's battlespace success in this area equates to competitive advantage. In the first stage this advantage is in information dominance but as this develops to encompass more and more systems (the vision that is NCW) this translates into battlespace dominance, NCW providing the way of optimising resources to achieve this purpose.

This vision is reflected in the linkages from measuring performance through to measuring force effectiveness and even policy effectiveness. Therefore it is important that measures should be introduced, at each stage, to ensure measurement (and validation) of the objectives.

3.2 Attrition

This paper is focused on the implications of the decision support process components suffering attrition. The questions that arise are:

- How does the system of systems perform when it suffers from equipment damage?
- Can cyber attack actually provide misinformation?
- Is there an issue of system of systems stability?

These, of course, are the technical issues addressed to the lower Measures of Merit levels. More importantly is consideration of the how this degradation impacts on warfighting capability. Associated is the impact of manpower loss in the context of NCW. This extends beyond 'front line' personnel through various levels to those who are responsible for the maintenance of equipment. In many cases the number of people who actually understand the full complexity of an individual system is limited. When integrated into a system of systems this becomes even more fraught! Additionally, in the days of multinational defence corporations who may be supplying more than one party in a conflict, objective analysis becomes even more complex!

Cyber attack takes many forms. Indeed in most cases the successful attacks are those which exploit an unknown weakness. It is therefore conceivable that an attack could change data or add new data. Ideally the system would be able to distinguish such data but thought needs to be given to the assessment of the impact of a successful attack.

The final question is the question of stability - is the transition from full effectiveness abrupt and if so, under what conditions? This is discussed below.

3.3 Styles of Failure

The performance of complex system under stress is complex and the nature of failure of system of systems is incomplete. Obviously there will be performance limitations of any systems. Usually there is sufficient redundancy for high loading and limited component failures to have minimal impact. A network centric system of systems potentially will substantially outperform conventional systems in most circumstances – see Fig 1. However at a certain point the system will start to overload and it is considered that catastrophic failure might well occur. This will be as a result of one or more of the following:

- Data/Information overload
- Damage to components
- Cyber attack
- Manpower loss

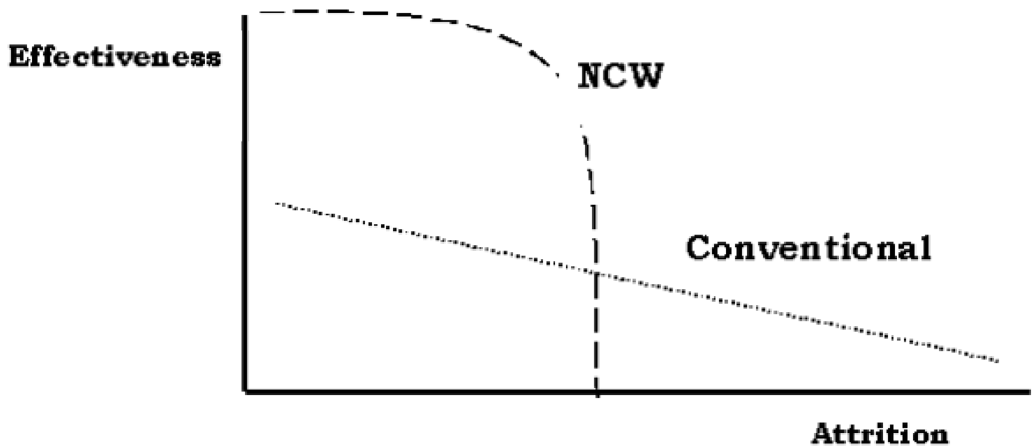

Figure 1: Relationship between C2 Effectiveness and Attrition.

Whether or not this hypothesis is valid depends on a number of factors, not least on where system boundaries are drawn! However what is clear is that there is a need to further investigate this area to evaluate the implications for force effectiveness.

4.0 DEVELOPMENT OF NETWORK CENTRIC CONCEPTS

4.1 Recognised Inhibitors

It is recognised that there are a number of technology areas that need to be developed before NCW becomes fully viable. Similarly the understanding of related human and organisational behaviours in virtual organisations, especially related to command structures, is still limited. Evaluation of the overall system must take account of these factors.

4.2 Emerging Technologies

Network Centric Warfare is an emerging concept that is only likely to become viable in the next two decades. The incorporation of emerging technologies is crucial for success. Optimum use of resource will only be obtained if the criteria applied to evaluation are also used for the assessment of the emerging technology.

4.3 Authority and Responsibility

Currently machines largely operate in ways which have been predetermined. For example, a machine would have a list of people who are permitted to see certain information and would rigorously enforce this requirement. This formality has certain advantages in normal operation. However it is possible to conceive of (but not predict) instances when this rigorous separation may need to be overruled. In human based systems it is easy to see how this would be achieved, through the exercise of authority and with it a responsibility that in the circumstances a breach of the rules was for a ‘higher good’.

In developing network centric concepts it will be seen that the issue of authority and responsibility needs to be adequately covered. The extreme need for this is likely to occur if an effective cyber attack were launched. Information from the system of systems may lead to a conclusion that is contrary to the (human) logic of the commander on the ground or in an HQ. A human judgement must be capable of being inserted into the system (with all the current ‘checks and balances’).

4.4 Planning

The radical nature of NCW means that long term planning should recognise the emergence of this powerful but innovative approach. It is likely that approaches based on incremental, budget-based, risk avoidance and historical extension will be found wanting. Technology based approaches offer significant risk as this paper has sought to outline. Scenario-based and capability-based planning approaches may well be most valuable, provided that sufficient consideration is given to the issues of attrition and that due recognition is given to the nature of ‘system of systems’.

5.0 MINIMISING VULNERABILITIES

5.1 Technology Watch

Technology never stands still! The vulnerabilities and options for attack of NCW will constantly develop. The application of technology watching approaches should enable those developing systems not only to utilise new approaches to optimise their own systems but should also make them aware of new and emerging threats to their own systems from adversaries.

5.2 Management

Vulnerabilities can be minimised by the used of appropriate management techniques. However to be successful the issues that need management must be clearly delineated. The use of technology must be managed with regard to warfighting needs, not allowing the technology needs to become dominant. This has significant organisational implications, developing an appropriate paradigm that takes account of stakeholder aspirations, whilst suitably managing expectations!

5.3 Technological Solutions

Various technologies are maturing that potentially could provide at least partial solutions. These are given as examples of the fact that technology is moving forward. However, assessment of network centric solutions must recognise that rapid technological developments will impact on the effectiveness of system of systems.

The use of arbitration (taking a number of independently derived solutions and using arbitration to identify errors) is emerging for use in secure systems. This has its roots in avionic systems which, with their need for providing timecritical and accurate information, use multiple systems to produce a number of results with 'majority voting' identifying any systems errors.

A significant number of programmes in both civil and defence sectors are looking a range of approaches using distributed systems that can produce secure, reliable and resilient results. These provide greater resistance against failure but their value has to be measured not only by their reliance but also their performance in failure. Again the final measure is the impact on force effectiveness.

6.0 THE WAY AHEAD

6.1 Research

The full concept of NCW is at this stage still in its infancy. It is anticipated that over the next 20 years there will be significant strides in realising effective integrated system of systems. What is almost certain is that what will the solutions realised will have features that we cannot imagine at this time. Research will continue to play a key part in the development of network centric solutions.

6.2 Implementation

Effective learning comes not only out of the laboratory but also from the lessons learnt from current (and past) systems. Over-ambitious planning and procurement have often led to non-optimal systems and there is a need to balance desires with that which can be achieved in a timely and cost effective manner. The analysis of alternatives [5] is complex especially when the issue of cost is encountered. It is important that the measures of merit used are independently assessed otherwise there can be unintentional bias.

6.3 Management

Known problems can be managed. This paper has underlined the fact that, like all new technologies, NCW brings benefits but also produces fresh issues. The issues should not be allowed to obscure the benefits and the solution lies in the way in which systems are managed. In particular NCW emphasises the need to view the support infrastructure (and its management) as an integral part of the whole equipment capability. There should be seamless management from sensor to shooter including C4I.

6.4 Doctrine

The impact of new technologies and structures (that are implicit in NCW) will result in new doctrine being developed. This must ensure that the impact of attrition will be minimised. This is a complex matter and will impact on evaluation.

6.5 Assessment

Assessment of the impact of attrition must be carefully undertaken. The modelling of systems must be capable of reflecting manpower and equipment attrition as well as the impact of cyber attack (perhaps the most difficult to model!). However assessment is not the end and, with the evaluation of alternatives [4], enable systems matching needs (and providing optimal cost benefits) may be procured.

7.0 CONCLUSIONS

'Full Spectrum Dominance' [5] will, to a greater or lesser extent, embrace NCW concepts. Evaluation of systems of systems requires consideration of the impact of attrition. This consideration extends well beyond availability and quality of service issues through the impact of battle damage, manpower attrition and cyber attack to force effectiveness. It moves from dimensional parameters to measures of force effectiveness.

The NATO Code of Best Practice [4] provides a valuable framework. However the evaluation should not simply be a passive analysis producing negative views but assist in engaging a positive review of the options that can be taken to overcome these issues. Above all it enables the effects of attrition in complex systems with high degrees of interdependence to be evaluated in a structured manner.

8.0 REFERENCES

[1] Alberts, D.S., Garstka, J.J. and Stein, F.P., *Network Centric Warfare*, US Department of Defence C4ISR Cooperative Research Program – February 2000.

[2] Hughes, J.A. et al, *Some 'Real' Problems of 'Virtual' Organisations,* Lancaster University 1998.

[3] Bunker, Robert J., *Five-dimensional (Cyber) Warfighting: Can the Army After Next be Defeated through Complex Concepts and Technologies?,* U.S. Army War College – August, 1998.

[4] *Code of Best Practice for Command and Control* – NATO – Revised Edition 2002.

[5] AoA Handbook, *A Guide for Performing Analysis of Alternatives,* Office of Aerospace Studies – June 2000.

[6] *Concept for Future Joint Operations* – US Department of Defense – May 1997.

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AUTHOR BIOGRAPHY

John Erbetta is with the UK Defence Science and Technology Laboratory. He read Engineering at University and then undertook postgraduate studies in systems engineering and later gained an MBA. With extensive experience in both public and private sectors, he is the author of a number of papers.

The Code in Practice – "Communications are the Key"

George A. Pickburn
Defence Science & Technology Laboratory
C134 Portsdown West
Fareham
Hampshire PO17 6AD
UNITED KINGDOM

gapickburn@dstl.gov.uk

ABSTRACT

This paper describes how the NATO Code of Best Practice on the Assessment of C2 has been applied within the UK procurement project to acquire a new generation of formation level communications.

***Key Words**: Command, control, assessment, best practice.*

1.0 A HISTORY OF C3I MODELLING

Operational research (OR) has addressed many topics and issues in its relatively short history. Most of the dark corners of corporate, industrial, and governmental competence have been illuminated by the bright light of OR. Some clients of the art have even complained at the brightness and have contrived to deflect the beam, perhaps even far enough to dazzle the decision-makers themselves.

One area of particular obscurity concerns investment in information generation, handling, fusion, and dissemination, known collectively as information management. In all domains, not just the military, information systems investment has proven difficult to justify in terms relevant to the central business objectives of the enterprise being served.

1.1 The 'Pre-History'

In the military domain, information and command & control are inseparable, although it is arguable that C2 is a considerably wider term than information management. It entails issues of morale and motivation, for example, although even these might in some minds be merely further forms of 'information' to be handled and processed. The ingredients of communications (C3) and intelligence (C3I) are recent additions to the mix of dimensions of the information 'problem', but they do not fundamentally change its nature. There are from time to time attempts to add further richness: the 4th C (for consultation) is glimpsed but rarely these days. It is notably present in NC3A's title.

The origins of OR, paradoxically for newcomers to the business, lie in issues arising from the interplay of:

- people as decision makers,
- sensed information (with attendant uncertainty), and
- the potential of platforms/fire channels to achieve desired ends.

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The classic example is the work carried out in World War 2 on UK air defence in the Battle of Britain.

Why is this a paradox to newcomers?; because we find ourselves here, some 60 years later, arguing for a re-balancing of the conduct of OR in favour of this broader view despite the progress of the intervening years.

1.2 The History

Much operational research, particularly in the military domain, has adopted a single technique of direct or 'literal' simulation. This paradigm entails modelling the motion of platforms of interest in three dimensions, with an overlay of probabilistic consideration of weapon delivery, impact, and detonation, where appropriate. In this approach, there is, at best, only implicit representation of information and knowledge, and it is usually not considered to vary within the representation. There is no human presence in the simulated environments, and acts of communication are not represented. It can be appreciated that this representation is a long way from reality. Effectors contrive to present themselves in the right place at the right time to engage with the opposition without any need for communications channels and the intelligence and orders they provide.

1.3 Modern Times

That notwithstanding, useful studies have been conducted during the 'history' phase in which C3I issues have been given a place. Their inclusion has usually been contrived through judicious use of intermediate parameters 'tweaked' to represent for example, different information states, or organisation policies. There is a sense in which this approach is fully legitimate, but it must be acknowledged that from the perspective of a customer for an OR study, it might not be perceived as transparent and so not legitimate.

Such thinking led the NATO Defence Research Group to propose the formation of an Ad Hoc Working Group to consider the question of what could be done with existing modelling approaches and methods to represent C3I factors, so allowing the C3 equipment agenda to be taken forward with assessment support. The Group's Report [1] noted that whilst C3I studies were not completely frustrated by the perceived lack of methodology, there were certainly improvements in approach which could be specified and codified for wider consideration and application. Amongst these was the recommendation that models should be built with a C3I perspective *at their foundation*, a suggestion which has been adopted as policy by UK defence practitioners. DRG Panel 7 accepted the recommendation of the AHWG Report that a Research Study Group (RSG) be formed to "promote and co-ordinate C3I modelling activities". This became RSG19 (later SAS 026) tasked to formulate and draft a code of best practice (COBP) in command and control assessment. UK authorities later produced a condensed version of the COBP which has now been adopted by SAS026 UK has also produced a risk register tool for C3I assessments, based on the COBP, to assist its own staffs.

1.4 Today

The code of best practice [2] is now an established part of the UK analysis and assessment scene. It has been briefed to senior decision makers in the UK MoD, and is regularly cited in the research programmes which support the UK's acquisition programme. It has even been used as a touchstone of best practice for domains of assessment other than command and control.

To illustrate such usage, he remainder of this paper is devoted to illustrating the UK's use of the COBP through its application to the assessment of proposed investment in new communications systems for UK forces, in particular the replacement of our ageing Ptarmigan 'formation' level land communications system, a project known as Falcon.

2.0 COMMUNICATIONS SYSTEMS ASSESSMENT IN THE UK

2.1 Introduction

In UK practice, the assessment of communications equipment and systems has three key components: the physics of propagation and the engineering of electronic devices, and the logical behaviour of digital systems. In the UK, models have been created which deal with each of these independently, and with mixes of all three. The best models, though also the most complex and so most expensive, make due allowance for the impact of analogue properties on digital behaviour. Note, however, that no representation of message content or the consequences of message arrival is attempted in these models.

2.2 Physics

This area of modelling addresses generation of signal power, inter-visibility of emitters and receivers, propagation including terrain and, where appropriate, ionospheric effects, and antenna design. The performance of each link is characterised by the signal to noise (S/N) ratio it achieves. A good example of this class of model in UK practice is the Communications & Electronic Warfare Simulation (CEWS) which has been through many generations in support of land based communications and electronic warfare optimisation and acquisition.

2.3 Digital Communications Systems

This class of models is often a derivative of, or a component of, the design process of digital communications systems. The model is comprised essentially of an emulation in software of the system's behaviour. Much of the real system software is capable of being incorporated into the emulation. Validation is clearly a less significant issue for such models. A typical output from this class is insight into the robustness of a given communications protocol under the deleterious impact of interference or counter measures. However, note that each system design will tend to spawn its own tailored simulation toolset with restricted applicability to other communications systems problems.

3.0 COMMUNICATIONS PROCUREMENTS IN THE UK

3.1 Introduction

The UK is currently engaged in four key communications procurement projects bridging all levels of command from tactical to strategic:

- Bowman will provide tactical services to the British Army in the field,
- Falcon will link formation level entities such as battlegroups, and their command infrastructure,
- Cormorant offers services to joint command, and
- Skynet will provide long-haul satellite-like services to all defence entities.

3.2 Bowman

Bowman will operate at the tactical level, and will comprise HF, VHF, UHF, Personal Radio, voice & data services. It will also automatically determine the position of each radio and report that position over a broadcast net. It will be secure and counter-measure resistant. It replaces the current Clansman system of HF and VHF manpack and vehicle mounted radios.

3.3 Falcon

At formation level, Falcon will offer voice and data services to all UK Forces and Services, replacing the Ptarmigan system of land communications and the RAF's Tactical Trunk System (RTTS). It will enable joint and combined warfighting with a wide range of allies. Falcon will be a deeply incremental acquisition in four phases.

3.4 Cormorant

The formation of the UK Joint Rapid Deployment Force (JRDF) made evident a requirement for bridges between Sea/Air/Land Service Joint Force Component 'HQ' Units, to enable Joint command to be exercised. The Cormorant procurement will satisfy this requirement.

3.5 Skynet

The existing Skynet programme of UK satellite communications is moving to a new generation of services to be provided by a public-private partnership arrangement. The next tranche will be known as Skynet 5 and will be comprised of satellite and other long-haul system technologies.

3.6 UCS

The totality of UK communications ambition is the generation of a Unified Communications System (UCS) in which all services required are offered to all users on a transparent, high availability basis. The roles and relationships of the systems being procured is shown in fig. 1. It should be noted that there are other equipments in service or procurement with which Falcon must be compatible:

- RAF Tactical Trunk System (RTTS;
- Local Data Communications Network (LDCN) also known as the Deployable Local Area Network (DLAN), offering communications services within airfield environments; and
- Gateway provision to other nation's systems (GATE).

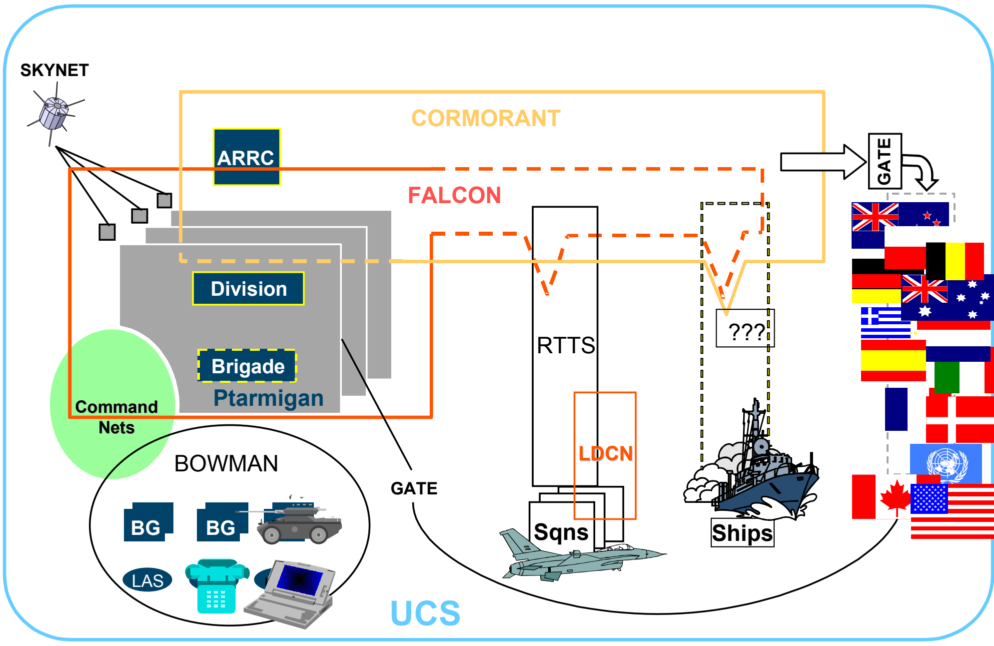


Figure 1: UK Communications Systems.

4.0 THE COBP – THE "BEST PRACTICE" PROCESS

The central concern of RSG19 was the perceived need for a clearly described sequence of actions to specify how best practice in C3I assessment could be exercised. The process agreed is shown in fig. 2. The process orientation of the Code has proven very helpful in offering a defined route through the complexities of the Falcon procurement. The process description is used in this paper to describe how the Code has impacted upon the approach which is being employed in the Falcon Assessment.

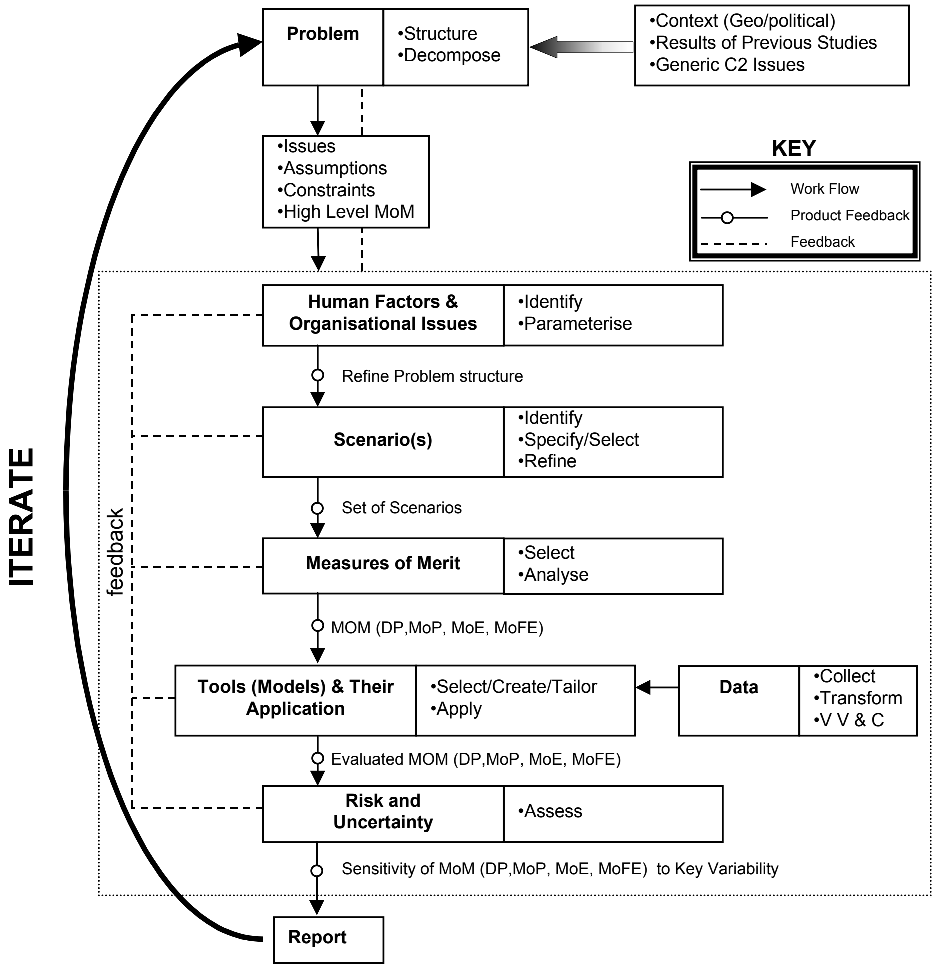


Figure 2: The COBP Process for C3I Assessment.

4.1 Assessment Context, Existing Knowledge & Issues

The context of the Falcon procurement is operations in both joint and combined circumstances and in a wide range of operational scenarios. There is also a managerial imperative to follow the precepts of the UK "Smart Procurement" initiative. For example, the project has been configured as a programme of four increments in order to reduce the risks arising out of the increasing pace of technology development. Existing studies relevant to Falcon include those on Bowman operational benefits, Cormorant operational benefits, and the requirement definition study for Falcon. This latter study aimed to identify in operational terms why the system was needed, as well as to give outline indication of the justification for the proposed scale of investment. Generic command and control issues for the Falcon procurement include the impact of communications systems properties on flexibility of UK forces in the light of changing doctrinal approaches and structural developments.

4.2 Problem Structure & Decomposition

It has usually been assumed in similar previous acquisitions that new communications technology is inherently a good thing. However, a number of difficult, not to say disastrous, acquisitions in both military and civil government domains has persuaded decision makers and their advisers that a new approach is necessary. The key realisation is that the purpose of investment is the delivery of benefits, both operational and financial. The essential structure of the 'problem' domain for Falcon is, therefore, identification and quantification of the benefits (and disbenefits) of the modernisation of communications infrastructure. In the Falcon assessment, we have conducted a benefits identification workshop amongst the military operators and communicators. This enabled the assessment team to map the generating links between the benefits required from the investment and the (already declared) User Requirement. Note that the User Requirement is conventionally expressed in terms that are wider than benefit delivery for usually sound military reasons.

The decomposition of the assessment for Falcon resulted in the following areas of decision-maker interest:

- Options for the use of technology,
- Migration paths from legacy to future systems components,
- Doctrinal development (manoeuvre and pace of operations),
- Options for different operational organisations,
- Different procurement modes,
- Different equipment suppliers,
- The significance of boundaries with related projects.

It is expected that further factors will be identified as the Falcon programme evolves through its incremental procurements and associated expenditure submissions.

4.3 Human Factors & Organisational Issues

Human factors figure in increasing strength in UK MoD thinking and policy as demographic development and trends in the employment market make themselves felt. The MoD response to these developments has been to seek yet further efficiencies in the deployment of human resources.

Equipment design has been subject to tests of human ergonomic compatibility for many years. Above that, task design is now firmly on the human factors agenda. The next level of concern is the design of co-operating teams of human actors; this is organisation design. UK MoD force development and doctrine agencies are again showing substantial interest in the link between HQ design and operational effectiveness. As budgets are squeezed and front-line forces are reduced, there are inevitable questions about the size and shape of the human command and control organisation needed to employ them effectively.

UK R&D management has responded to these developments by progressive investment in programmes to identify the relevant aspects of human performance and to quantify them in the form of executable models. This work has been reviewed in a survey of guidance on the use of HF knowledge in C2 operational analysis [3].

For the Falcon era and operational applications, the prime human factor issue is the flexibility of HQ staff to optimise their roles and activities. In respect of organisation, the issues are the impact of doctrinal drivers and constraints on the effectiveness and efficiency of HQ organisations.

4.4 Scenarios

Communications are, of course, a constant feature of every scenario. The key scenario issues are the obvious ones:

- capacity to satisfy the demand made of the systems during the most intensive phases of operations, including the implications of concurrency of operations in different theatres;
- security within NATO and coalition operations;
- the variety of terrain and force dispositions within the relevant geographies.

To meet these requirements, the Falcon assessment will address five different scenarios drawn from the UK's standard set of MoD approved scenarios. The range covers intensive warfare as well as peacekeeping operations, both including a variety of terrain. A further key requirement for coherence between studies will be met by exploitation of scenarios already developed for use on other studies.

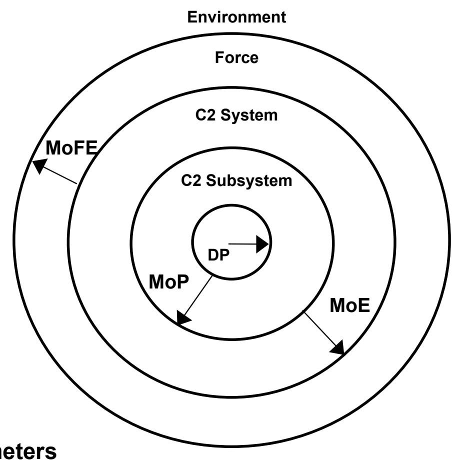
Within each scenario, the assessment will examine a group of military *vignettes*:

- deployment,
- enemy air strike on an HQ,
- deep operations by joint forces,
- transition from peacekeeping to warfighting,
- coalition operations, and
- exit from theatre.

The *vignettes* offer an operational level of consideration of the benefits by the military experts.

4.5 Measures Hierarchy

The COBP advises that the measures adopted to assess the benefits of the proposed investment should be construed as a hierarchy. The COBP text illustrates the general purpose hierarchy as a set of nested measures, as in figure 3.



Legend

DP :	**Dimensional Parameters**
MoP :	**Measures of C2 System Performance**
MoE :	**Measures of C2 System Effectiveness**
MoFE :	**Measures of Force Effectiveness**

Figure 3: The General Hierarchy of Measures of Merit.

In the Falcon programme of assessment, the factors which reflect decision-maker concerns and interests and are therefore most prominent in the measures hierarchy are as follows:

- **Parameters** (DP): radio and system architecture descriptors, organisational architectures, doctrinal conditions, project boundaries;
- **Measures of Performance** (MoP): Picture completeness, HQ planning efficiency, operational pace, organisation flexibility;
- **Measures of Effectiveness** (MoE): ground controlled by friendly units, enemy destroyed, casualties prevented;
- **Measures of Force Effectiveness** (MoFE): battles won, campaign success.

4.6 Tools, Models etc.

To quantify these measures, the Falcon assessment will adopt four key tools:

- simulation of battlefield actions and headquarters planning activities;
- benefits analysis by multi-criteria decision analysis (MCDA);
- vignette analysis by military advisory panels; and
- analytical/simulation modelling of communications networks.

Figure 4, below, indicates the likely flow and points of tool application, together with the sources of information and stakeholders which are crucial to a successful analysis.

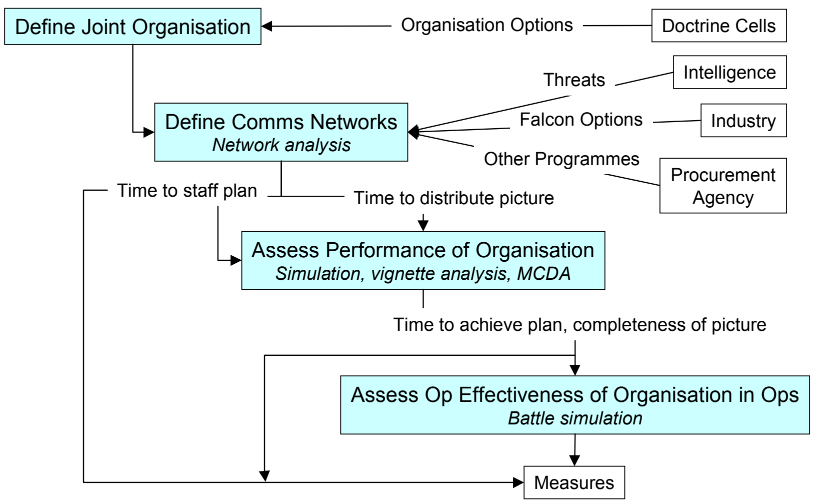


Figure 4: The Assessment Tools and Process.

4.7 Risk and Uncertainty

In Falcon, there are four prime risks which the assessment programme must address and manage: late option definition, late cost data, uncertain boundaries, and incorrect information exchange requirements.

The first is that the options for procurement will be insufficiently well defined to permit timely analysis by the methodology. This risk is being attacked in two ways: a set of generic option types will be defined with the support of technical expertise as the procurement programme matures which will be used to characterise the likely performance of the final offered solutions. With good judgement, it should be possible to argue that the actual options offered are but a small step from the generics which the analysis has addressed in detail. Secondly, the bidding companies are to be asked to carry out their own network modelling to determine the performance of their bid against a pre-declared set of key parameters.

The risk of late cost data for each option arises essentially from commercial sensitivities, exacerbated by the negotiation process as the competition moves to closure. It will be managed by a similar mechanism to the problem of option definition, namely, generic cost-able options reflecting the likely commercial offerings.

It is expected that Falcon boundaries will remain uncertain or in flux even as procurement proceeds to later increments. This is natural as the competence and efficiency of the 'Falcon' component of the total communications network will remain relatively uncertain until equipment is actually fielded. The benefits and costs which may be legitimately attributable to Falcon will therefore clarify only slowly, so inhibiting the cost-effectiveness assessment. This risk is very difficult to manage. The approach being employed is to operate a stakeholder and procurement team liaison mechanism called (at present) the Scientific Studies Working Group (SSWG).

Uncertainty in the information exchange requirement which Falcon will be called upon to support is in effect a combination of uncertainties in a range of determining parameters. It is being addressed in part through the SSWG (mentioned above), and partly through the vignette analysis being conducted with the assistance of operational field staffs who are best placed to conjecture likely trends in the demands for messaging and other traffic.

4.8 Reporting

Reporting in of the Falcon assessment will be via the standard UK format known as the Operational Analysis Supporting Paper (OASP). This format is relatively new and is designed to bring together all the evidence supporting the need for procurement, the scale of investment proposed, and the cost-effectiveness of the options. It achieves these aims by drawing on previous work and current studies, and by outlining and justifying the tools and methods used. In this regard, the OASP concept supports the principles of thorough, validated analysis set out in the Code of Best Practice.

The OASP forms one of the supporting papers to the business case which is eventually submitted to the UK expenditure approving authorities. It is also used extensively in supporting briefings to MoD staffs during the submissions process. Many senior MoD staff will, indeed, not see the OASP, instead forming their judgement on the basis of the briefing alone. This is a key feature of the streamlined MoD decision-making process under the Smart Procurement initiative.

4.9 Iteration

A global mechanism for addressing uncertainty and risk is iteration through the methodology. Sensitivity testing will be employed in the Falcon assessment to identify key investment and other variables. The robustness of each offered solution to uncertainty in the environmental and investment variables will be identifiable by the sensitivity tests.

In addition, some global iteration has been employed within the assessment to increase confidence in its eventual success. A Requirement Definition Study was conducted some two years ago to both explore the methodology then proposed, and to examine the justification for the proposed investment in Falcon. This was a most valuable exercise in that it succeeded on both counts. It demonstrated that Falcon almost certainly represented a better route for investment than further acquisition of platforms and weapons. It also revealed a lack of sensitivity in the simulation-based, single MoE methodology which was then being used for assessments of this kind. One result has been the enrichment of the Falcon Mo'E' hierarchy based on a more diverse set of tools and methods.

The iteration so far conducted has been highly beneficial in gaining the confidence of the customers of the assessment in MoD and Procurement HQs. It has also allowed the programme to engage with (so far) two generations of operational staffs, which though it allows trends of operational thinking to be discerned, also introduces a contribution of uncertainty into the process.

5.0 CONCLUSION

For the Falcon project, the Code of Best Practice has proven itself a powerful aid to good study design. It has enabled the design to meet the concerns of the procurement customer, the operational staffs, and internal analysis peer review. It has been particularly successful at addressing the 'system of systems' complexities of the communications systems. It has also opened up the domain of communications and command and control procurement to the doctrine and organisations staff. Finally, it has offered a helpful standard agenda and vocabulary amongst analysis practitioners involved in C^2 and communications / electronic warfare assessments in the UK, and with their customers.

The way ahead as seen from the UK now is two fold: further progressive application of the code to projects in the C^2 domain, and use of the Code, and its shortened UK version, in foundational education of analysts.

6.0 REFERENCES

[1] "The Impact of C3I on the Battlefield", NATO DRG Technical Report AC/243(Panel 7)TR/4, dated 21 Feb 1994.

[2] "Code of Best Practice (COBP) on the Assessment of C2", NATO RTO-TR-9 AC/323(SA)TP/4, dated March 1999.

[3] "Human Decision-Making in OA: Knowledge Requirements and Guideline Structure", Sheppard, C., Mathieson, G., Corrie, N., DERA/CDA/SEA/AIR/CR000070/1.0, dated August 2000.

AUTHOR BIOGRAPHY

George Pickburn has spent his career in operational research and analysis for all military domains, latterly taking a special interest in command, control, and information systems. He has also served as a 'red team' scrutineer of business cases for systems procurement, an experience which gave him extensive experience of assessment failure modes.

Re-Assessing Dismounted Operations in Complex Terrain using the NATO CoBP for C2 Assessment

Edward C. Brady
SPI
1488 Evans Farm Drive
McLean, VA 22101
USA

bradyspi@worldnet.att.net

Stuart Starr
MITRE
7515 Colshire Drive, MS N650
McLean, VA 22102-7508
USA

starr@mitre.org

ABSTRACT

The assessment of dismounted operations in complex terrain remains one of the most challenging problems for the military analysis community. Recently, a study was performed by the U.S. Army Science Board to identify the operational capabilities that were needed to enhance the effectiveness of these operations, with emphasis on C4ISR. This paper uses the NATO Code of Best Practice (CoBP) for C2 Assessment to characterize the key attributes of that study and to highlight its findings.

To establish a context for the study, an extensive data mining activity was undertaken to clarify the key issues and to identify preliminary insights. This activity focused on "lessons learned" reports from actual operations and after action reports from recent experiments. Based on the results of this data mining, a set of five vignettes was selected that spanned an interesting set of levels of conflict and environmental conditions (e.g., a reverse slope, treeline attack in rugged terrain; defense of a convoy against an ambush in an urban environment; use of low collateral damage weapon technologies in complex terrain; floor clearing operations in a building; humanitarian assistance in a small village). In several of these scenarios, consideration was given to human performance and behavior (e.g., speed at which individuals could move over rugged terrain when wearing loads of specified weight). In many of these scenarios, loss exchange ratios provided the greatest insight into the impact of proposed changes in systems, tactics, techniques, and procedures on force effectiveness.

One of the key study challenges involved the acquisition of data of sufficient resolution (e.g., on the order of 1 meter, consistent with Digital Terrain Elevation Data (DTED) level V). These data were employed using a variety of assessment tools. These included several constructive simulations (e.g., JANUS, Joint Conflict and Tactical Simulation (JCATS)) and an agent based model (MANA). These tools proved adequate to provide preliminary assessments of the measures of merit (MoM) of interest. In all cases, variations around the baseline were assessed to determine the sensitivity of the results. In addition, by exercising MANA, the agent based model, it proved feasible to compute cumulative probability distribution functions of the key MoM (Blue losses) to facilitate the sensitivity assessment.

The major product of the assessment was the identification of key technological and operational capabilities that have the potential for transforming dismounted operations in complex terrain. It is notable that the majority of these transformative capabilities involve C4ISR (e.g., intelligence preparation of the battlefield for complex terrain). The paper also identifies recommended initiatives to enhance the assessment tools and

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capabilities (to include virtual and live M&S) to perform enhanced future assessments of dismounted operations in complex terrain.

1.0 PROBLEM FORMULATION

This paper is based on work that the Analysis Panel performed in support of the U.S. Army Science Board (ASB) 2001 Summer Study on the Objective Force Soldier/Marine Team. The focus of this activity was on dismounted operations in complex terrain.

The Terms of Reference (ToR) for the 2001 ASB Summer Study called out four major objectives:

- Characterize improvements in lethality, survivability, C4ISR, and logistics required to yield a more effective Objective Force Soldier/Marine Team across the operational spectrum.
- Evaluate connectivity between the Future Combat System (FCS) and the Objective Force Soldier/Marine Team.
- Assess current and projected research, development, and acquisition efforts. Focus on effectiveness, weight reduction, power, and affordability.
- Recommend alternative Science & Technology investment strategies and map the technological advances from present to future.

As a benchmark, the Summer Study sought to identify Science & Technology initiatives that, cumulatively, would enhance the effectiveness of the Objective Force team by a factor of ten. Note that these initiatives included improvements in lethality, survivability, C4ISR, and logistics. Thus, although the study was not restricted to C4ISR, that issue area proved to be a dominant dimension of the assessment.

Originally, the Analysis Panel was tasked with helping to synthesize the outputs from other panels to help support the prioritization of recommendations. These other panels included Fightability Technologies, Power System Technologies, and Weight Considerations. It soon became apparent that it was not feasible to implement the role of quantitative synthesizer and prioritizer given the dynamics of the Summer Study. Most of the panels planned to develop their proposed recommendations just prior to the conclusion of the Summer Study. Given the time and resources required to prepare and employ relevant analysis tools, it was not possible to perform the desired assessments.

However, during the nine months prior to the Summer Study, two key roles for the Analysis Panel emerged. First, to provide a context for the other panels, the Analysis Panel was able to perform assessments that identified key initiatives where advances could enhance the effectiveness of operations substantially. These insights enabled the other panels to focus their efforts on areas where the operational payoffs would be greatest. Second, the Analysis Panel was cognizant of the fact that the assessment of dismounted operations in complex terrain was in its infancy. Thus, it also sought to identify options to improve the set of tools that the community had to undertake this difficult and important task. These two objectives became the *real* issues that the Analysis Panel pursued.

To assist in the formulation of the problem, the Analysis Panel undertook two parallel initiatives. First, it began a data mining activity that persisted for the duration of the study. One prong of the data mining focused on reports that documented the results of prior operations. This included assessments of recent dismounted operations in urban theaters such as Somalia and Chechnya (Reference 1). Those assessments served to identify specific C4ISR issues that needed to be addressed (e.g., intelligence preparation of the battlefield). In addition, the Analysis Panel reviewed the reports of recent experiments that had been conducted using dismounted units employing innovative systems and concepts in urban environments (e.g., the US Marine Corps' Project Metropolis (Reference 2)). Those results also served to identify key issues that required assessment (e.g., the need for enhanced communications at the squad level).

In addition to these data mining efforts, the Analysis Panel visited a wide variety of organizations. These included: training testbeds where the panel was able to observe simulated dismounted operations in small, instrumented villages; operational sites, where the panel was able to speak to the operational community; analysis organizations, where the panel was able to assess the capabilities and limitations of existing assessment tools and to receive briefings on recent analyses; virtual M&S testbeds where the next generation of tools is being developed; and laboratories where the panel was briefed on promising systems and concepts.

The output of these efforts was a rich enumeration of key issues (for both concepts of operations and materiel) and an understanding of the state of the art in existing and emerging assessment tools.

2.0 SCENARIOS

These data mining activities and visits made it clear that dismounted operations in complex terrain had to be assessed in the context of a broad set of stressing scenarios (see Figure 1). These scenarios were selected based on a variety of considerations. First, in analyses performed in support of the 2000 ASB Summer Study, evaluations were performed of the effectiveness of alternative mounted operations in the context of a hypothetical Kosovo scenario. Those analyses revealed that the ensuing dismounted operation would be complex and hazardous. Those results provided the initial conditions for the first scenario, attack of a deeply dug in Red squad by three dismounted Blue squads. Second, in discussions with various operational and analytic organizations, three challenging issues for dismounted operations were identified: protection of a convoy from ambush in an urban environment, interdiction of supplies in an urban environment with minimal collateral damage, and clearing floors in a building occupied by Red forces. Finally, based on operations in East Timor, New Zealand forces expressed interest in the challenges associated with distributing relief supplies to natives using materiel and concepts of operations that minimized the risk to Blue forces. Representatives of Germany also indicated interest in this issue. Thus, a range of contexts was selected that represented stressing situations. Although the set of scenarios was not exhaustive, it served to provide a broad spectrum of challenging perspectives.

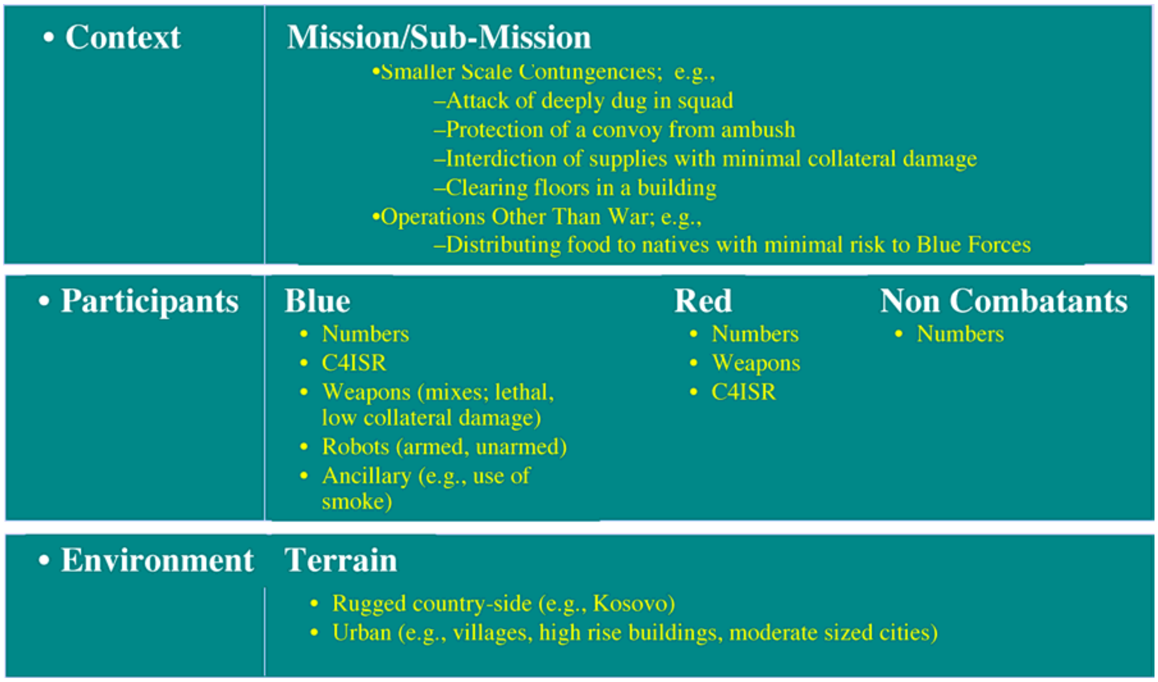

Figure 1: Scenarios.

For each of the contexts selected, several capabilities for the participants were selected, with appropriate variations about those values. In the case of Blue forces, attention was focused on five key variables: the number of Blue personnel in the operation (particularly for the OOTW context); the sophistication of the C4ISR systems (e.g., quality of communications, sensors) and their ability to perform key C4ISR functions (e.g., situation assessment); the type and mix of weapons systems available to Blue (including existing weapons as well as future lethal weapons (e.g., Objective Individual Combat Weapon (OICW)) and low collateral damage weapons (e.g., foam, sedating agents)); the presence of robotic agents with varying levels of functionality (e.g., sense-only; sense and engage capability) and concepts of operation; and the availability of selected ancillary equipments including the use of smoke and exoskeletons. In general, the capabilities of other participants were characterized by selecting representative levels of numbers and, where appropriate, weapons and C4ISR.

Finally, since the focus of the study was on complex terrain, a variety of different terrain conditions were explored. These ranged from a rugged countryside (representative of the terrain characteristic of Kosovo) to a spectrum of urban environments (including small villages, high rise buildings, and moderate sized cities such as Sarajevo). In general, a specific terrain condition was selected for each of the contexts cited above.

3.0 MEASURES OF MERIT

Consistent with the variety of scenarios considered, several hierarchies of Measures of Merit (MoMs) were employed (see Figure 2). For each of the contexts assessed, an appropriate measure of mission accomplishment was selected. These included “taking Red’s position” (for the three Blue squads attacking a deeply dug in Red squad), “surviving the ambush” (for the convoy attacked on the outskirts of Sarajevo), “clearing the building” (for the floor clearing operation in the high rise), “interdicting the flow of supplies” (for the use of kinetic and LCDW weapons in and around a bridge), and "delivering food to the natives" (for humanitarian operations in East Timor).

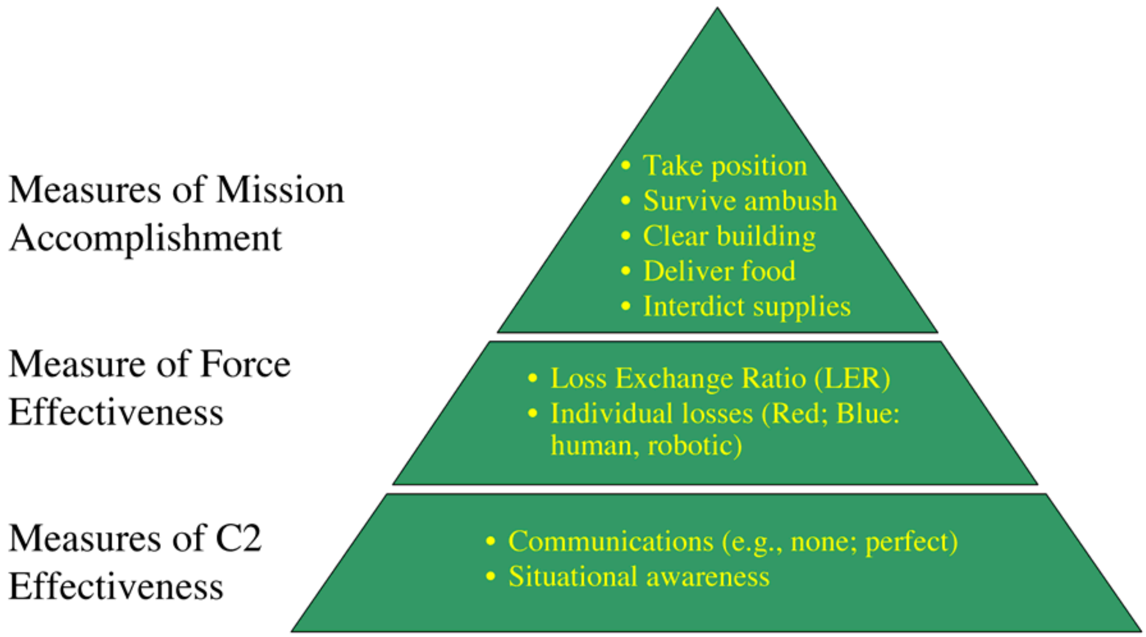

Figure 2: Measures of Merit (MoMs).

At the next level of the hierarchy, Measures of Force Effectiveness were defined. In all cases, the dominant MoMs involved the losses incurred in operations and the loss exchange ratios. For those cases featuring robotic agents, the losses for those entities were monitored.

Finally, measures of C2 effectiveness were tailored for the scenarios of interest. For example in the floor clearing operation, assessments were performed for the bounding cases in which Blue force communications was perfect and non-existent. In addition, in the assessment of three Blue squads attacking a deeply dug in Red squad, effectiveness was evaluated as a function of the quality of Blue's situational awareness.

4.0 HUMAN FACTORS

Since the 2001 ASB Summer Study was specifically interested in a variety of human factors (e.g., the weight of the equipment that an individual could carry and still be mobile and effective), it was important to address human issues directly in the assessments. This was accomplished in two specific ways.

First, data were acquired from Natick, the US Army's Soldier System Laboratory, to characterize the performance of individual soldier as a function of weight carried (e.g., distance covered as a function of weight carried; speed of movement as a function of weight). These results were factored into the assessment of the attack of a deeply dug in squad.

Second, when New Zealand analysts assessed operations in East Timor, they concluded that individual human behavior would have a significant impact on the outcomes. This included consideration of the motivation of the participants, their discipline, and the change in their behavior when a squad member was injured. This led to the search for tools that had the ability to reflect those factors.

5.0 DATA

During the course of the assessments, the Analysis Panel discovered that data limitations posed significant barriers. These limitations were of particular significance in four key areas.

First, in order to assess small squad operations in complex terrain, it was discovered that terrain resolution on the order of 1 meter (i.e., Digital Terrain Elevation (DTED) Level 5) was needed. Since data to that resolution were unavailable for Kosovo, this posed a dilemma. To resolve the dilemma, the assessment team began with available DTED Level 5 data from Hunter-Liggett, CA, and augmented the terrain with vegetation features to emulate Kosovo terrain.

Second, when the Analysis Panel visited the Shuggart-Gordon Range at Ft. Polk, LA, they found a useful environment for gaining insight into operations in urban environments. Even though many units had employed this environment in exercises, little effort had been made to transform and mine the data. In addition, instrumentation limitations restricted the type of data that could be collected.

Third, the effects of factors such as fatigue, stress, and sleep deprivation were of great interest in the study. However, there are relatively little available data on the effect of these factors on small squad performance.

Finally, there was great interest in assessing mission effectiveness in the 2020 time frame. However, given the relatively primitive state of knowledge about the future concepts and systems that are likely to be in use at that time, the Analysis Panel was compelled to make educated guesses about those data.

6.0 TOOLS

During the course of its visits, the Analysis Panel was able to identify a number of tools that were well suited to the issues of interest. These tools included a variant of JANUS, developed and employed by the RAND Corporation, and the Joint Conflict and Tactical Simulation (JCATS). The later tool, developed by Lawrence Livermore National Laboratory (LLNL), is used widely for the assessment of small unit operations by a variety of institutions (e.g., Joint Warfighting Center, IDA). In addition, the Analysis Panel was introduced to MANA, an Agent Based Model developed by researchers in New Zealand to prepare for OOTW. Taking advantage of these tools and researchers cognizant of their strengths and weaknesses, the Analysis Panel was able to direct studies for the five major scenarios of interest.

While these tools appeared to be adequate to support a preliminary assessment of most of the issues of interest, it was clear that a next generation of tools was needed to explore these issues further. Several promising initiatives were identified during the course of the Analysis Panel's deliberations. In the category of virtual M&S, the USMC Combat Decision Range provides a useful, inexpensive vehicle to explore the effectiveness of alternative mixes of systems in the context of selected scenarios (e.g., peacekeeping in Kosovo). In the longer term, if the individual soldier is represented adequately, the Joint Virtual Battlespace may be able to shed light on issues associated with the interfaces between mounted and dismounted operations. As noted above, several live M&S for urban operations are in existence (e.g., Shuggart-Gordon Range, Ft. Benning) and they could be of increasing value if their instrumentation and data analyses capabilities were to be enhanced.

In the long term, it would be prudent to orchestrate these tools in a model-experiment-model paradigm, to take advantage of the strengths of these tools and to compensate for their weaknesses.

7.0 REPRESENTATIVE FINDINGS

To illustrate the kind of results that the Analysis Panel generated consider the products that emerged from the use of JANUS by RAND to assess the use of dismounted forces to engage a deeply dug in Red squad in complex terrain. Initially, RAND assessed the contributions of options that are indicated in Figure 3, *one at a time:* smoke, Objective Individual Combat Weapon (OICW), body armor, signature reduction, and indirect fire support (IDF). As you can see, several of these options provided some improvement (notably the OICW), none of which would be regarded as spectacular. Note, in particular, that the addition of smoke actually reduced effectiveness because it resulted in shorter range, more lethal engagements for Red.

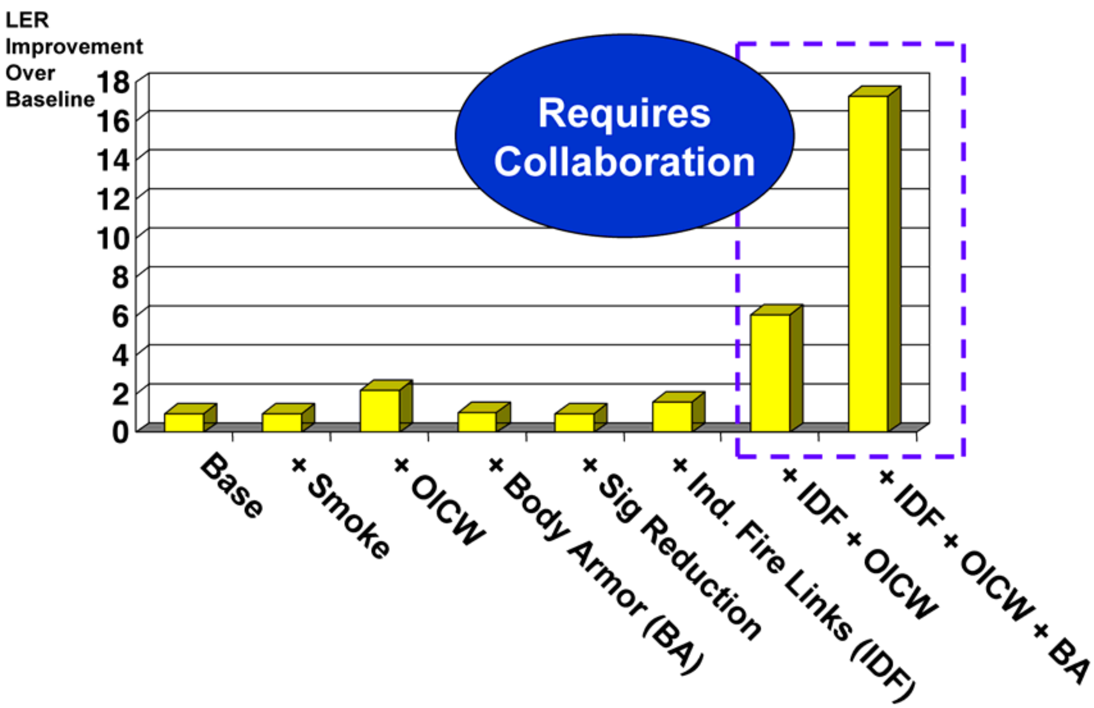

Figure 3: Results for Deeply Dug in Squad in Complex Terrain.

The Analysis Panel then moved to the next phase of the analysis and considered adding *combinations* of these options to the base case. The first variant added indirect fire with the OICW. That served largely to nullify the effect of Red's machine guns (which were the major killer of Blue Forces, even when they were equipped with body armor). Subsequently, when the Analysis Panel added the body armor to the mix there was a substantial improvement in effectiveness (i.e., a 17-fold improvement in LER over the base case). At this stage, with the elimination of Red's machine guns, Blue's body armor provides extremely effective protection against Red's small arms, substantially reducing Blue's losses. Although it was not explicit in the model, you need the ability to communicate and collaborate amongst the Blue forces in order to conduct this type of activity. In addition, this operation requires a sophisticated level of situational awareness by the Blue Force.

These analyses suggest that there is a substantial potential for synergy among materiel and tactical options if they are implemented in a synchronized fashion. However, it must be anticipated that Red will attempt to modify its concepts of operations to counter these actions. Thus, additional analyses are required to explore the potential interactions among Red and Blue countermeasures.

8.0 SENSITIVITY ANALYSES

Figure 4 gives some indication of the sensitivity analyses that were performed to determine the robustness of the findings for individual vignettes. The variations refer to excursions around the base case of three Blue squads attacking a deeply dug in Red squad in complex terrain in good weather. It can be seen that among the excursions the assessment team explored the impact of weather, parametric variability of selected factors (e.g., reducing the signatures of Blue forces by 50%, 75% and 88%), alternative concepts of operations (addition of preparatory fires that are either fire for effect or precise), alternative force mixes (e.g., partial fielding of OICW), the addition of new technology (e.g., unattended ground vehicles with weapons), and combinations of options. This systematic approach served to identify options that were worthy of future exploration.

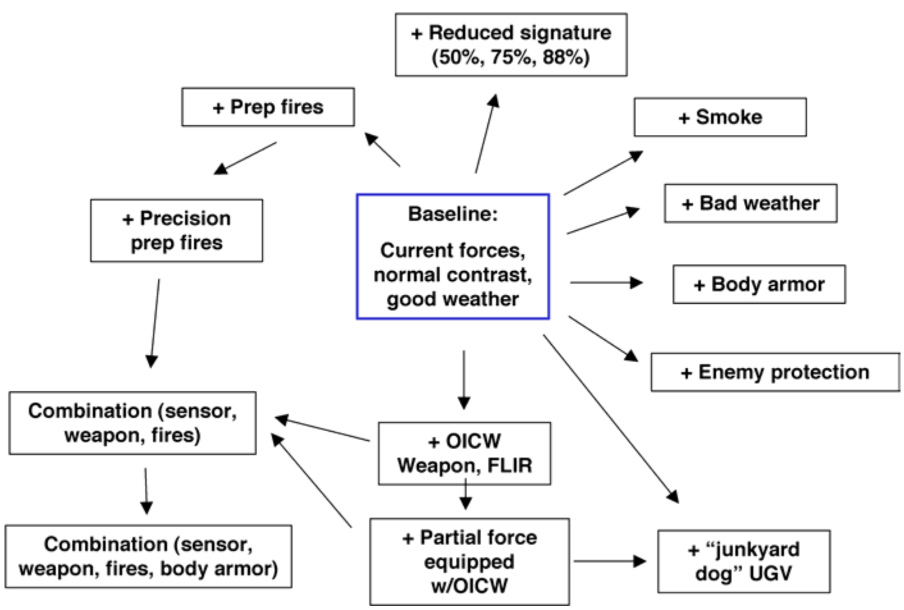

Figure 4: Cases Assessed in Sensitivity Analyses.

9.0 CONCLUSIONS

Based upon the assessment activities, the Analysis Panel identified key capabilities that are needed to perform effective dismounted operations in complex terrain. These potential capabilities have been organized into six categories: lethality, survivability, mobility, C4ISR, sustainability, and foundational (e.g., training, experimentation, systems perspective) (see Figure 5). All of these capabilities are potential areas for improvement. However, there are two key points to emphasize.

• **Foundation** - *Operational Preparedness (e.g., Training)* - *Experimentation*	*Integrated System Design (e.g., System of Systems)*
• **Lethality / Effects** - *Responsive Reach Back* - Non-Lethal - Room Clearing Weapons - Small, Desired Effects Weapons	LCDW (e.g., SASO) Counter Sniper *Direct and Indirect Fires*
• **Survivability** - *Detect/Avoid Surprise Threats* - Signature Management	Active Protection Passive Protection
• **Mobility** - Transport Heavy Load - High Sprint Speed - *Vertical Tactical Mobility*	Soldier Vehicle Support Interfaces Enhanced Endurance
• **C4ISR** - *IPB for Complex Terrain* - *Detect, Classify, IFFN, Track and Fuse (e.g., Rooms, Tunnels, Jungles)* - Decision Aids for Planning, Execution - *Information Operations*	*Simulation on Demand (e.g., Novel COAs, Realistic Rehearsal)* Complex Terrain • *Comms (Intra/Inter Echelon)* • *Precision Navigation/Tracking*
• **Sustainability** - *"Never Too Late" Supply*	Fault Tolerant Systems Power Management

Figure 5: Key Capabilities (*Transformative*).

First, the panel reviewed these capabilities and highlighted those that could truly transform the nature of dismounted operations in complex terrain. Those capabilities that, under selected conditions, could give rise to an order of magnitude in improvement are highlighted in Figure 5.

Second, it is interesting to note that the bulk of these "10X" capabilities are clustered in the area of C4ISR. Thus, the primary challenge to the other panels of the ASB Summer Study was to identify and explore the technologies that are needed to make these C4ISR capabilities a reality.

The Analysis Panel derived several broad insights as a consequence of these assessments. First, when comparing options, it proved vital to formulate and compare appropriate mixes of doctrine, organizations, training, materiel, leadership and education, personnel and facilities (DOTML-PF). Thus, it was not adequate to vary a single factor (e.g., materiel) while keeping all of the other factors fixed. This was particularly apparent in the assessment of options featuring the addition of robots. In those cases, the concepts of operation made a major difference in the effectiveness of the options.

Second, many of the results of interest are highly scenario dependent. As an illustration, there was interest in assessing the contribution of smoke (to conceal friendly operations) to operational effectiveness. In the scenario in which several squads attacked a deeply dug in Red squad, the addition of smoke actually decreased the survivability of the attacking Blue force (e.g., it reduced the range at which Blue forces were engaged). However, when smoke was used to counter the effects of a Red ambush of a convoy, it enhanced survivability (e.g., the addition of smoke reduced the loss of Blue trucks by 54% and the loss of Blue scouts by 37.5%). This example illustrates the importance of assessing options over a broad set of scenarios to ascertain their robustness.

The assessment also served to identify several other important needs. First, there are a significant number of on-going efforts that could be of considerable value if they are exploited adequately. As an example, it is important to enhance the instrumentation of key testbeds (e.g., Shuggart-Gordon) and to evaluate systematically the results from forces employing those testbeds. Second, the Analysis Team gained valuable insights from assessments undertaken by the US Marine Corps. Those activities should be broadened to include joint and combined forces to assess the problem in a broader context. Finally, although existing tools proved useful, they are limited in their flexibility and uncertain in their validity. Steps should be taken to enhance individual tools and to orchestrate them to leverage their strengths.

10.0 CoBP LESSONS LEARNED

This activity served to provide insight into the NATO CoBP in two dimensions. First, since one of the authors had participated in the generation of the NATO CoBP, that experience was extremely useful in the planning and execution of the study. It helped guide the formulation of the problem (e.g., stimulated the data mining initiative), led to the selection of a broad set of scenarios, guided the explicit selection of a hierarchy of MoMs, helped in the selection of appropriate tools, and stimulated the systematic implementation of sensitivity studies.

In addition, the NATO CoBP proved to be a valuable tool to guide this *post mortem* of the study. Retrospectively, it has served to help highlight the study's strengths (e.g., the systematic addressal of the major issues highlighted in the NATO CoBP) and weaknesses (e.g., inability to acquire needed data on the environment and on selected human factors). Consistent with the dictum of the NATO CoBP to assess the issues iteratively (going from broad shallow assessments to deeper, more focused assessments), areas for follow-on assessment are relatively clear. In addition, several areas are now apparent that we could have improved. For example, we should have established stronger coordination mechanisms with other stakeholders (e.g., the other panels participating in the Summer Study) to ensure that we were fully conversant with their issues and were able to provide timely feedback and guidance based on the results of our assessments.

11.0 REFERENCES

[1] "Handbook for Joint Urban Operations", Joint Staff, 17 May 2000.

[2] "MOUT Battalion Level Experiments – Experiment After Action Report", Project Metropolis, Marine Corps Warfighting Laboratory, February 2001.

12.0 ACKNOWLEDGMENT

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Simulation Interoperability for the new RNLA C2 WorkStation

Jeroen Beckers, Wim Huiskamp, Freek-Jan Toevank, Oscar Abbenhuis
Command & Control and Simulation Division
Operations Research Division
TNO Physics and Electronics Laboratory
P.O. Box 96864
2509 JG The Hague
THE NETHERLANDS

j.j.beckers@fel.tno.nl huiskamp@fel.tno.nl toevank@fel.tno.nl abbenhuis@fel.tno.nl

ABSTRACT

The C2 WorkStation (C2WS), developed by the Royal Netherlands Army (RNLA), is a configurable application platform and information system that provides generic functionality to support the Command and Control process. The C2WS supports the users in building and maintaining a Common Operational Picture (COP) in order to enhance the Situational Awareness. The C2WS has conversion modules for ATCCIS and RNLA legacy systems e.g. the Integrated Staff Information System 'ISIS' and the Battlefield Management System BMS.

TNO-FEL has recognised an opportunity to support the C2WS assessment activities by ongoing experimental studies on coupling of simulation tools with the C2 architecture. The simulators will be used to provide stimuli (e.g. unit detection or movement) to the C2WS and thus objectively assess the C2-systems involved and facilitate training and education of the users of these C2-systems.

Our architectural approach is to provide a software gateway to the modern High Level Architecture (HLA) simulation standard. The link to HLA provides the possibility to connect many modern simulation components to the C2WS architecture. The HLA development process provides a generic approach to simulation interoperability for the C2WS. As a first demonstrator of interoperability between the C2WS and an HLA Simulation system, a Decision Support System (DSS) has been selected. This DSS concentrates on Course of Action (COA) analysis. The COP defined in the C2WS is copied to a planning overlay on the C2WS and transferred to the DSS. The DSS evaluates this input using simulation and the results from the analysis are routed back to the C2WS in the form of a new planning overlay. This overlay can then be evaluated by the C2 operator.

Future applications of the addition of Simulation components to the C2WS will be a more extended Decision Support functionality (e.g. route planning, fire support planning, etc.) and the use of simulators for C2 training of commanders.

This paper presents an overview of the architecture and the demonstrator under development. Application areas: (1) Test and assessment (as part of the Acquisition process), (2) Training & Instruction, (3) Operations Support.

Key Words*: C2 – Simulation Interoperability, Simulator Architecture, HLA Middleware.*

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1.0 INTRODUCTION

This paper addresses the approach used by TNO-FEL to develop and demonstrate concepts for interoperability between C2 system and Simulations. Simulation interoperability for C2 systems enables applications in training of army staff officers, operations support and procurement, assessment and evaluation of C2 systems. The project is aimed specifically at the C2 Workstation (C2WS), a new system for the Royal Netherlands Army (RNLA), which is in an early stage of its development.

The requirements for the design of the C2-Simulation interoperability are: flexibility, scaleability, robustness and compliancy to international standards.

As a first demonstrator of interoperability between the C2WS and an HLA (High Level Architecture) based Simulation system, a Decision Support System (DSS) was chosen, which concentrates on Course of Action (COA) analysis. The DSS analyses plans, prepared on the C2WS, using simulation and results from the analysis are routed back to the C2WS as a new planning overlay, for evaluation by the C2 operator.

The next section addresses the need for interoperability and the general concept of coupling C2 systems to Simulations. Section 3 explains the interoperability approach followed for the C2WS; section 4 discusses the High Level Architecture which has become the *interoperability standard* used in the Simulation domain. The remaining sections discuss the system architecture, implementation issues and some preliminary results and conclusions of this project.

2.0 LINKING C2 SYSTEMS TO SIMULATION MODELS

Linking C2 systems to Simulation systems has many potential applications:

- Simulation systems can stimulate the C2 system by providing data that simulates the ‘real-world’. This information will now appear to have been received from peer C2 systems. In this way a simulated COP (Common Operational Picture) is created that is based on a simulation scenario. Applications of this technique are: assessment of C2 systems (performance, user interface etc.), assessment of C2 operator capabilities or even training of C2 operators.
- The simulation can provide the C2 operator with operational decision support by executing ‘what-if’ scenarios. These scenario’s can support the operator in his decision making process (e.g. mission planning or assessment of alternative COA’s).
- New or experimental parts for an existing C2 system can be evaluated before purchase or even before development of the component by replacing an existing component of the C2 system with an embedded simulation. Simulation systems can be ‘initialised’ from the existing COP in the C2 system and a simulation run can be started based on this information, assessing what-if scenarios.

The advantage of using simulations as a tool for stimulation of C2 systems, as apposed to ‘role players’, is that the simulation has a consistent, controlled and reproducible behaviour, which allows objective assessment of system and/or operator performance. TNO-FEL has recognised an opportunity to support the C2WS assessment activities by ongoing experimental studies on coupling of our simulation tools with this C2 architecture. The aim of the research is to develop a flexible and future-proof approach to the C2-Simulation interoperability problem. First we need to clarify what we really mean by ‘interoperability’.

Interoperability is the degree to which entities are able to co-operate in achieving a common goal. There are many interpretations of the concept of interoperability between computer systems. It varies from having a network connection and being able to transfer files (e.g. email) to using exactly the same applications at all systems and completely sharing the information they process. A commonly used form of interoperability is *'information interoperability'*, because it offers optimal connectivity between systems, while preserving maximum independence. Information interoperability is defined as the ability of systems to automatically exchange and interpret information that is common to those systems [Ref 1].

In this paper we focus on information interoperability that is achieved by the *automated exchange and interpretation of structured information* between systems. With minimum user intervention, C2 systems and Simulation systems must be able to *automatically* interchange certain information and utilise that for further processing. This means that the information must be *structured*, because this enables functionality such as distribution by subscription on certain topics, presentation of information and filtering by specific selection criteria. The emphasis here lies on the exchange of *information* (rather than 'free format' databits), preserving its meaning, integrity and context. Structured information is described formally by a *'Datamodel'*. The datamodel thus represents the foundation for information interoperability.

In the most common case where many systems have to exchange information, standardisation of a common 'interface' is a key factor to achieve information interoperability. Otherwise, dedicated interfaces are needed between every pair of interconnected systems, leading to an exponential grow of the number of interfaces required. Preferably the exchange should not depend on proprietary products, such as database management systems and communication systems. The key notion for information interoperability is *standardisation*. By having common agreements on which information is exchanged, in what format, and under what conditions, it becomes easier to allow systems of different types to interoperate.

3.0 C2WS

The C2WS is a configurable *application platform* and information system that provides generic functionality to support the Command and Control process. The C2WS supports the users in building and maintaining a COP in order to enhance the Situational Awareness.

The C2WS is being developed at the RNLA C2 Support Centre, with cooperation of TNO-FEL. The C2WS system architecture comprises three layers whose basic functionality can be segmented into: presentation services, business services, and data services [Ref. 2].

The **presentation services layer** is responsible for gathering information from the user and presenting information to the user using the services of the business services layer.

The **business services layer** is responsible for end-to-end *business transactions* such as maintaining *roles*, *contexts* and *business objects* and the logic that applies within these concepts.

The **data services layer** is responsible for storage, retrieval, maintenance and integrity of data. The data services layer is also in charge of publishing as well as subscribing and listening to data on the network.

The information exchange in the C2WS environment is based on commercial of the shelf publish/subscribe services and a tailored information exchange language [Ref. 3]. The information exchange language is based on the RNLA C3I Architecture (C3IA) Information Model (C3IA-IM) for C2 applications within the RNLA. C3IA is more generic than the fixed set of descriptive attributes of ATCCIS.

The C2WS has conversion modules for RNLA legacy systems such as the Integrated Staff Information System 'ISIS' and the Battlefield Management System 'BMS'. A translator service shall be made available for translating C3I information to proprietary systems such as the German C2 system 'HEROS'.

At the time of writing, the C2WS supports GIS functionality for placing units and lines/areas on the map. The network functionality is partly implemented, for example updates of the COP for a certain ‘context’ can be exchanged between different C2WSs. However a means for a new C2WS to hook into the network and receive the full current COP has not yet been implemented.

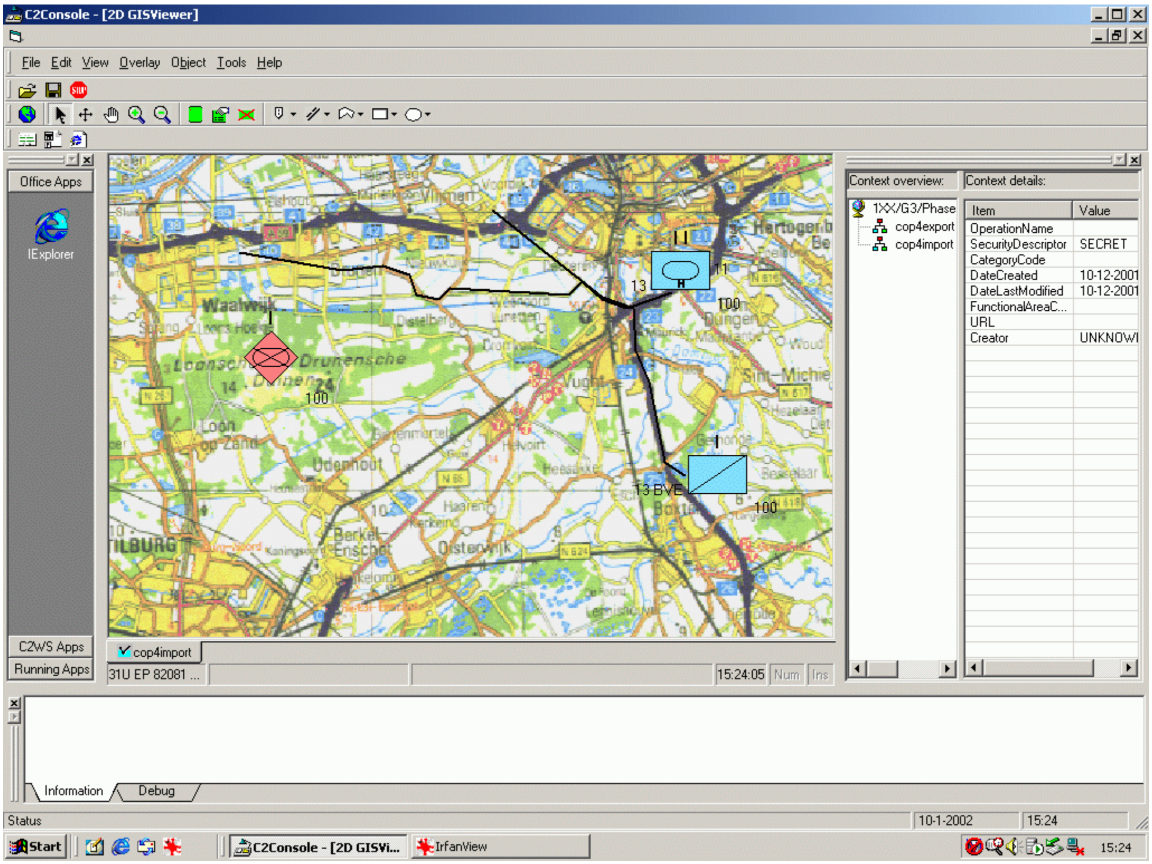

Figure 1: The RNLA C2 Workstation (Pre-Released Prototype, Sept 2001).

4.0 HLA

The High Level Architecture (HLA) is an architecture for reuse and interoperation of simulations [Ref. 4, 5, 6]. The HLA is based on the premise that no single simulation can satisfy the requirements of all uses and users. An individual simulation or set of simulations developed for one purpose can be applied to another application under the HLA concept of the Federation: a composable set of interacting simulations [See Figure 2].

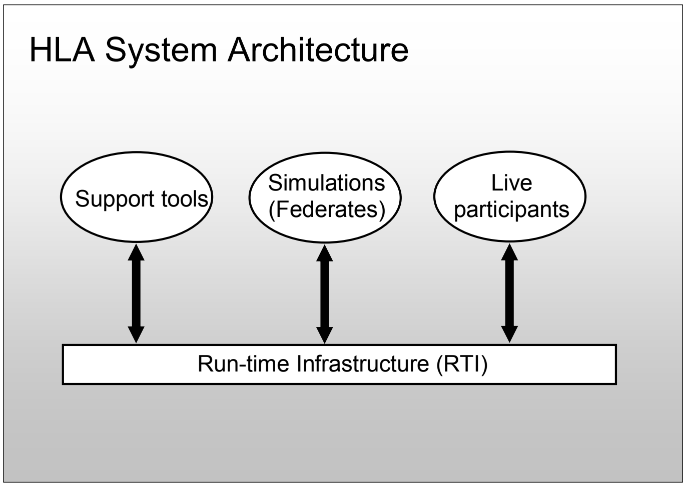

Figure 2: HLA Federation.

The intent of the HLA is to provide a structure that will support reuse of capabilities available in different simulations, ultimately reducing the cost and time required to create a synthetic environment for a new purpose and providing developers the option of different implementations within the framework of the HLA.

The HLA provides the specification of a common technical architecture for use across all classes of simulations: (a) *Virtual:* "Real people operating simulated equipment", (b) *Constructive:* "Simulated people operating simulated equipment" and (c) *Live:* "Real people operating real equipment on an instrumented training range". HLA provides the structural basis for simulation interoperability. The baseline definition of the HLA includes the HLA Rules, the HLA Interface Specification (IFSpec), and the HLA Object Model Template (OMT). The HLA interface specification defines many services that HLA provides to the application. These services include Object Management (publish/subscribe) and Time Management (i.e. synchronisation between distributed applications). The Federation Object Model (FOM) is the datamodel of the HLA Federation. The OMT is the standard format that is used in HLA documentation.

The HLA does not prescribe a specific implementation, nor does it mandate the use of any particular software or programming language. Over time, as technology advances become available, new and different implementations will be possible within the framework of the HLA. In February 1998, version 1.3 of the HLA specification was adopted by the US Defense Modelling and Simulation Office (DMSO) and in September 2000 it has been accepted as IEEE Standard 1516 for simulation interoperability. The HLA is a standard for use in the US Department of Defense and within NATO (NATO MSMP 1998). Development of a generic coupling between C2 systems and HLA thus provides the possibility to connect modern simulation components to the C2 environment.

One of the main components of HLA is the Run-Time Infrastructure (RTI). The RTI implements the HLA IFSpec and allows the user to invoke the RTI services to support run-time interactions among Federates and to respond to requests from the RTI. This interface is implementation independent and is independent of the specific object models and data exchange requirements of any Federation. At TNO-FEL we developed an HLA based middleware layer, called the Runtime Communication Infrastructure (RCI) [Ref. 7] which supports HLA. The RCI shields the developer from many intricate details concerning the usage of the HLA-RTI, including Data Distribution Management (DDM) [Ref. 4, 5, 6], when developing either a Component or a Federate. The RCI includes a C++ code-generator to translate the required HLA-OMT descriptions into easily accessible object-oriented classes The C2-Sim coupling approach described here is based on our RCI concept.

5.0 C2WS-BRIDGE FEDERATION

The first demonstration target of our project was to achieve interoperability between the C2WS and an HLA Simulation system. More specifically, the use of simulation as a Decision Support System (DSS), which concentrates on Course of Action (COA) analysis. The COP defined in the C2WS is copied to a planning overlay on the C2WS and transferred to the DSS. The DSS analyses this input through simulation and results from the analysis are routed back to the C2WS as a new planning overlay available for evaluation by the C2 operator. The Federation that was developed for this demonstration is named the 'C2WS-Bridge Federation' and consists of the following Federates:

- FedMan, this (optional) Federate was developed by TNO and is used as Federation Manager. It has online capabilities to initialise, monitor, start, stop, pause and abort the whole system. The Federation Manager also has the ability to monitor the activities of all participants and systems and take appropriate (planned & unplanned) action, to ensure a successful completion of the exercise;
- Decision Support Federate. This Federate is based on the 'Bridge' constructive combat simulation model developed by TNO-FEL for the RNLA. It is responsible for the simulation of ground and air brigade/division mobile operations. The Federate was modified to handle the input from the C2WS and deal with the required Objects and Interactions.

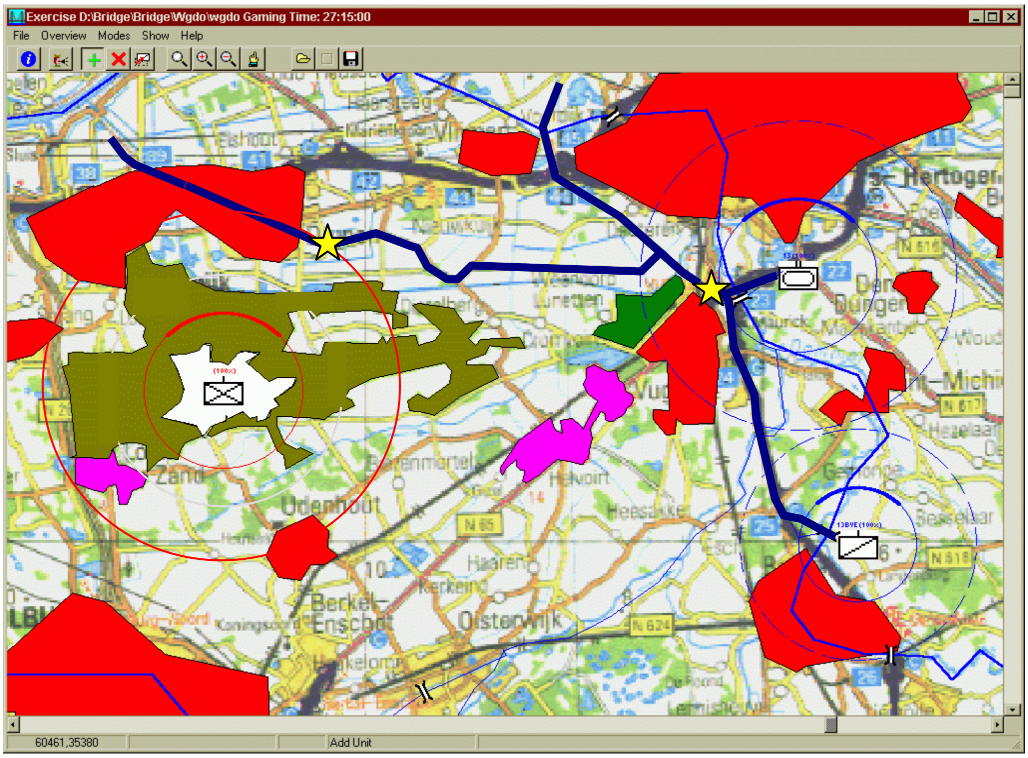

Figure 3: The DSS Tool Bridge (TNO-FEL Prototype).

- Stealth Federate, a 3D viewer into the virtual environment. This (optional) Federate is based on the available TNO-FEL Stealth from TNO-FEL's Electronic Battlespace Facility (EBF). The Stealth is interoperable with the Federation through a 'DIS/HLA Gateway' and thus demonstrates our capability to deal with 'legacy' DIS Federates;
- C2WS Federate, one or more (unmodified) C2WS applications (C2 GIS) manned by their regular RNLA operators. See figure 1.

The C2WS-Bridge Federation was able to adopt the DiMuNDS 2000 FOM [Ref. 8] (see next section).

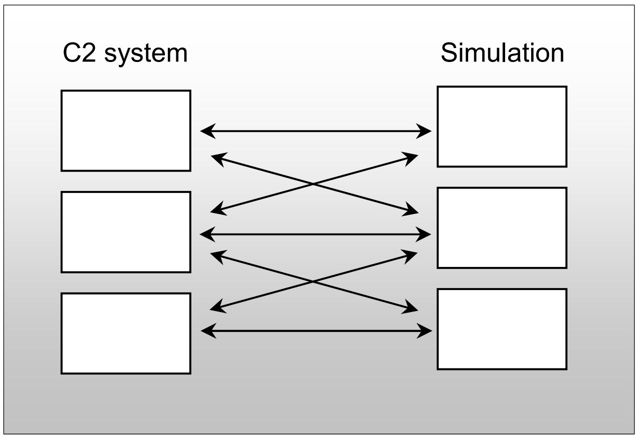

Figure 4: Tailor Made Connections.
(Not Fully Interconnected)

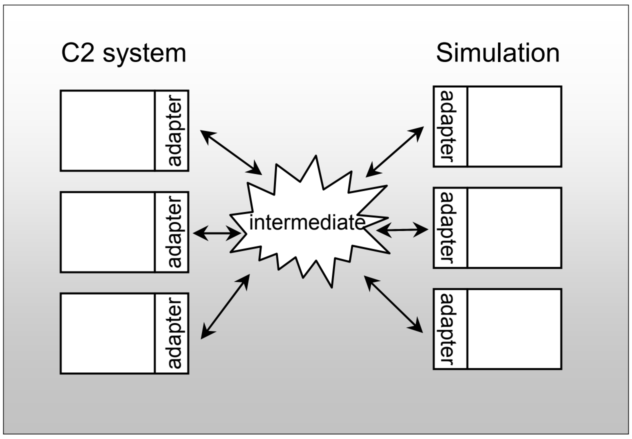

Figure 5: Connections using an Intermediate Layer.
(Fully Interconnected)

6.0 BRIDGING THE GAP

Previous attempts to couple C2 systems with simulations were often ad-hoc and resulted in tailor-made connections for every specific combination of C2 systems and simulation models. When one of the systems needs to be connected to another system or simulation, a new connection needs to be developed. This approach means a lot of work for both the C2-System and the simulation model, see Figure 4.

A more flexible approach is the use of an intermediate layer as show in Figure 5.

Once a system or simulation has a (tailor made) adaptor for the intermediate layer, the system can be connected to other systems or simulations without any additional work on the other sides.

The approach that was followed to achieve C2WS-Simulation interoperability resembles the 'intermediate layer' solution, however with an important difference: both the C2WS systems and the Simulation systems already support interoperability within their own domain.

The C2-System uses a commercial of the shelf product, TIB/Rendezvous (TIB/RV) from Tibco, to exchange information. The simulation systems use the HLA interoperability standard. A 'gateway' connects TIB/RV on one side to HLA on the other side (see Figure 6).

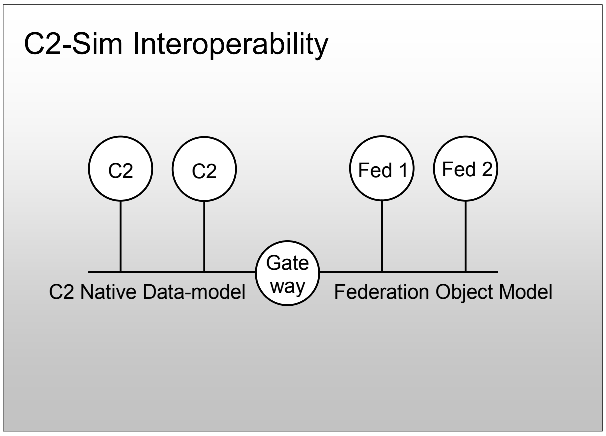

Figure 6: C2-Simulation Datamodel Interoperabilty.

In addition to interoperability at the technical level (protocols, networks etc), we also need to develop the information interoperability: bring the Datamodels inline and provide a two-way mapping for all relevant attributes (see Figure 6). HLA systems are connected to each other in a Federation and define their communication via a Federation Object Model (FOM). The FOM has to be agreed upon between the systems that need to be connected. For the C2-Simulation system a C2WS-Bridge Federation has been designed together with an initial FOM based upon the FOM used previously in the NATO DIMUNDS 2000 demonstration [Ref. 8].

This FOM describes four generic objects which are:

- Weather,
- Stationary,
- Mobile and
- StationaryMultiLocation.

The information that is exchanged via the FOM consists amongst other things of the position of the object and depending on the object information, for example status and speed. It is often impossible to directly map the information exchanged between C2-systems onto the FOM.

Table 1: Schematic DiMuNDS 2000 FOM Datamodel.

Object	Specialisation	Specialisation	Specialisation
Weather			
Stationary	Seaport		
	Pumping station		
	C2-centre		
	Corridor		
	Airbase		
	Depot radarsite		
	Bridge	CivilBridge	
		Combatbridge	
StationaryMulti Location	Special area		
	Minefield		
	Non lethal obstacle		
Mobile	Sea	Surface	
		Sub-surface	
	Air	Cruise missile	
		Air mission	Fixed-wing
			Helikopter
	Ground	Non-combat	
		Combat service support	
		Engineer	
		Sensor	
		Fire-support	
		Manouvre	
		Airdefence	HiMad
			ShoRad

In most cases it is necessary to combine information from the C2-system in order to get it mapped onto the FOM and vice versa. In an initial quick research the following fields were identified for a unit message that need adaptation before they can be mapped on either the FOM or on the C2 information.

Table 2: Data Mapping Fields (not exhaustive)

FOM	C2WS
ObjName	Name
PartyNumber	Nationality
Velocity	SpeedQty
Position	Position
Front	BearingAngle

A name in the FOM needed to be restricted to 10 characters, the FOM only knows of four different parties while the C2WS allows many more different nationalities, and the location of a unit in the UTM system of the C2WS needed to be translated into the relative map coordinates used by the FOM. Specific conversions and layout issues had to be resolved and implemented to realise any coupling between the two domains.

7.0 TIBCO-HLA GATEWAY

A TIBCO/HLA Gateway was developed for the purpose of incorporating a C2WS in the Federation.

The Gateway (see Figure 7) was implemented using two processes, one attached to the RCI (HLA middleware) and the other attached to TIB/RV (main component of the C2WS interoperability middleware from Tibco). Both sides use a broadcast (publish/subscribe) method to distribute data on the network. TIB/RV listens to messages on the network and places an image of the object/interaction data concerning the C2WS entities (to which a subscription was issued by the Gateway) in shared memory. The RCI process subsequently reads this data from shared memory and maps it onto the HLA-SOM via the RCI middleware. The same holds for communicating data from the HLA Federation to the C2WS world where TIB/RV publishes the object/interaction data received from the Federates in the Federation.

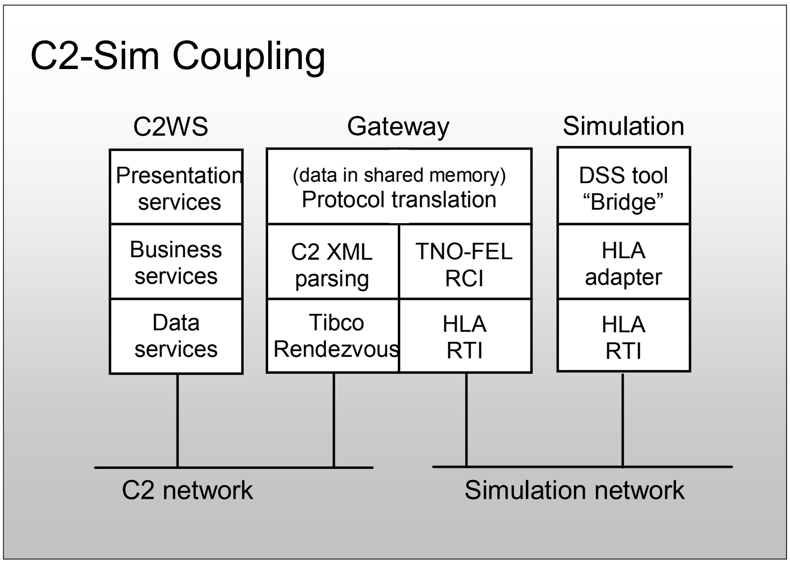

Figure 7: C2WS Federation with TIBCO/HLA Gateway.

The Federation was developed by (loosely) following the Federation Development and Execution Process (FEDEP) [Ref. 6].

The objective of the Federation was defined as:

- Demonstrate interoperability between constructive (wargame) simulations and C2 systems using HLA. The focus of the scenario and the simulation application is on features that are important for Decision Support.

The following documentation is typically produced in the FEDEP:

- *Federation Objectives, Requirements and Conceptual Model.* This provides details for FEDEP steps 1 (*Define federation objectives*) and 2 (*Perform conceptual analysis*). The document describes the statement of 'Federation Objectives', 'Scenario Requirements', 'Conceptual Model' and 'Federation Requirements'. Federation requirements described in the document serve as a vehicle for transforming objectives into functional and behavioural capabilities, and provide a crucial trace-ability link between the Federation objectives and the design implementation. The requirements are derived from the specification of the Federation Objectives and the high-level description of the Scenario.
- *Federation Scenario Document*; this document describes the scenario in full detail, the geographic location of interest, the nature and size of forces, in our total scenario represented by about 60 computer generated forces (CGF) units, the initial positions and the occurring events.
- *Federation Design and Development Document*; this document provides details for FEDEP steps 3 (*Design Federation*) and 4 (*Develop Federation*). This phase of the FEDEP is concerned with the detailed design of the Federation (including mapping of Federation Objectives and Requirements to Federates), the selection of and modification of existing Federates and the development of new Federates. The document describes the results of the selection process, the definition and development of their interactions (laid down in the FOM) and mapping of Federation objects/functionality on Federates. The document also details Federation agreements (e.g. Operating Systems, Tool versions, and co-ordinate systems).
- Documentation supporting step 5 (*Plan, Integrate, and Test the Federation*).
- *Federation Execution and Evaluation Document*; this document provides details for FEDEP step 6 (*Execute Federation and Analyse results*). The document also details hardware and network requirements and organisational aspects (e.g. machines, network port numbers, script and required staff list for rehearsals and executions, list of invited guests).

Inconsistencies in co-ordinate conversion algorithms used by different Federates often pose an additional problem. But in our case, the terrain databases used by constructive Federate (Bridge) on one hand and the C2WS Federate on the other hand, were identical and thus correlated. Only the usual conversion from map-co-ordinates to UTM, used in our FOM (and vice-versa), was called for.

8.0 RESULTS

The prototype demonstrator for the C2WS with DSS tool is capable of transferring a COP to the DSS tool. The user can try out several courses of action and transfer the resulting situation back to the C2WS as a planning overlay. The gateway handles a limited set of units and other C2 items, which shall be extended in further versions of the demonstrator.

Due to the early stage of the development of the C2WS, some cumbersome precautions have to be taken when demonstrating the simulation functionality. The updates of the COP from the C2WS are incremental, so only changes are broadcast to other stations. A full COP transfer for when a new C2WS is added to the network, or in our case, for simulation purposes, has not yet been implemented in the current version.

Concentrating on coupling this RNLA C2 system with a simulation component in such an early stage of its development has resulted in encouraging insights in the possible additional functionality required of the C2WS.

9.0 CONCLUSIONS

The demonstration of coupling a C2 system to a simulation tool using HLA is expected to achieve its overall objectives and received positive reactions from its audience. Some lessons learned so far from the project are:

- Use a single (authoritative) source for common data like terrain data, co-ordinate conversion algorithms, equipment and weapon parameters, etc.;
- Peruse for a standardised C2-Simulation Datamodel, represented in FOM format.

In addition to full compliance with HLA, the innovative architectural concept that was developed supports the key capabilities required for future C2-Simulation interoperability applications:

- An abstraction layer (or TNO-RCI middleware) and a code generator hiding complexities of the underlying interoperability standards and enabling simulation protocol migration with minimal changes to the functional implementation.
- A structured development process (the FEDEP), supported by appropriate tools, enabling migration of legacy simulations and COTS products to the new standard architecture;
- One single standard for all information exchange between systems is a solution that is unlikely to be ever achieved, even if we restrict the 'universe' to NATO C4I systems. The Gateway approach is therefore the optimal solution to allow interoperability between the different worlds that C2 and Simulation are today.

The (completion of the) design and the development of the C2WS falls outside the scope of our project. However, we do believe that future C2 systems will include the design requirement for interoperability with Simulations and the results of our project will therefore influence the development direction of the C2WS. The C2WS is on its way to become a useful and exciting new C2 system, reaching out to the useful and exiting new simulation standard HLA.

10.0 REFERENCES

[1] Eddie Lasschuyt, Marcel van Hekken, "Information Interoperability and Information Standardisation for NATO C2 – a practical approach", IST-2000 Workshop, April 2000.

[2] Command and Control Workstation (C2WS) 'Help'-documentation set, RNLA C2 Support Centre, 23 October 2000.

[3] C3I Architecture: Information Model, RNLA C2 Support Centre, 22 December 2000.

[4] Defense Modeling and Simulation Office (DMSO), "High Level Architecture for Simulations Interface Specification". http://www.dmso.mil/public/transition/hla/techspecs

[5] Defense Modeling and Simulation Office (DMSO), "High Level Architecture Object Model Template". http://www.dmso.mil/public/transition/hla/techspecs

[6] Defense Modeling and Simulation Office (DMSO), "Federation Development and Execution Process (FEDEP) Model". http://www.dmso.mil/public/transition/hla/techspecs

[7] Marco Brasse, Wim Huiskamp, Olaf Stroosma, "A Component Architecture for Federate Development", Simulation Interoperability Workshop, Fall 1999.

[8] Joost Hamers, Leo Breebaart, "Development of the NATO DiMuNDS 2000 Federation – An account of work".

[9] Wim Huiskamp, Henk Janssen, Hans Jense, "An HLA based Flight Simulation Architecture", Proc. AIAA Modeling and Simulation Technologies Conference, Denver, Colorado, USA, August 2000 (AAIA-2000-4401).

AUTHOR BIOGRAPHIES

Jeroen Beckers is a junior scientist at the Command & Control and Simulation Division at TNO-FEL. He holds a M.Sc. degree in Computer Science from the Delft University of Technology and his work concentrates on simulation scenario research and development, distributed simulation and development and visualisation of Virtual Environments.

Wim Huiskamp is a research scientist in the Command & Control and Simulation Division at TNO-FEL. He holds a M.Sc. degree in Electrical Engineering from Twente University of Technology, The Netherlands. He works in the field of High Performance Computing and Networking and specialises in design and implementation of distributed computer architectures. His research interests include system architecture, real-time simulation and autonomous vehicle technology. Wim was the project lead for several national and international simulation (and simulation interoperability) projects.

Oscar Abbenhuis is a research scientist in the Operations Research and *Business management* division at TNO-FEL. He holds a degree in Micro Electronical Systems Design from the Haagse Hogeschool in The Hague, the Netherlands. He works in the field of software engineering and specialises in design and implementation of software in various languages. His research interests include modelling and simulation, distributed computing and new technologies in the software field.

Freek-Jan Toevank is a scientist in the Operations Research and *Business management* division at TNO-FEL. He holds a M.Sc. degree in Econometrics and Operations Research from the University of Groningen, The Netherlands. He works in the fields of operational analysis, decision support and strategic policy development for the RNLA.

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Building up a Common Data Infrastructure ©

Mark R. Sinclair
VERIDIAN
Information Solutions Division
2101 Executive Drive; Tower Box 51
Hampton, Virginia 23666
U.S.A.
+1 (757) 825-4097
mark.sinclair@veridian.com

Dr. Andreas Tolk*
Virginia Modeling, Analysis & Simulation Center
Old Dominion University
7000 College Drive
Suffolk, Virginia 23435
U.S.A.
+1 (757) 686-6203
atolk@odu.edu

ABSTRACT

While the value of data for an individual study effort is well understood by the analytic community at large, aggregated worth of data is still astonishingly undervalued by many members of the OR study community. Data can be described as the fundamental elements of information and knowledge that comprises the corporate whole – consequently its aggregated value particularly when addressed in a context larger than an individual study is significantly greater than the sum of the parts.

Obtaining data is indispensable. To be effective it must be a continuous process within every study and can be not only very time consuming but also a very expensive factor in the total cost of a study effort. With the aggregate of available data growing with every study the situation becomes even more complex and the case for agreed community wide data management standards and techniques is made even stronger. Without these standards the analyst's ability to find the necessary data for an individual study effort by traditional means decreases exponentially and the ability to reuse existing data in future studies is reduced thereby increasing the cost of data.

To help the analyst to face these challenges, the NATO Code of Best Practice for Assessment of Command and Control (COBP) introduced a Data Section. This section already defines the application domains of data engineering, meta data modelling and efficient data re-use. However, the deeper value of these additional efforts – albeit a burden for the single study, especially for the initial efforts at introducing the respective techniques and tools – clearly show up when being seen in the broader context of multiple studies dealing with related topics.

This paper extends the application of the COBP data section beyond the scope of a single study into the broadened study community domain, including other Operational Analysts, C3I System Developers, Social Scientists, etc. Therefore, in this paper the necessary methodologies for applying the ideas of the COBP data section, thus enabling the reuse of data across different studies, will be highlighted A case will be made for a user community requirement for a common data infrastructure including some first ideas for technical implementations.

Key Words*: Data Engineering, Data Mining, Data Farming, Data Re-Use, Meta Data Modelling, Information Repository, Information Resource Dictionary System (IRDS).*

* The contributions to this paper have been conducted on behalf of the Industrieanlagenbetriebsgesellschaft mbH (IABG), Einsteinstr. 20, 85521 Ottobrunn, Germany, where Dr. A. Tolk worked until March 2002.

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1.0 INTRODUCTION

The role of data and its importance is acknowledged as fundamental to the conduct of a successful and intellectually sound study. However, in practice data often is neglected during the study preparations. Data is often seen only as something necessary to feed the respective tools and models to be used in the study. It is interesting that the tools and models are usually seen to be of high value whereas the data just is something that is needed “in addition” – not as the fuel that makes the tools run. It is of no great surprise that this view was represented in the first version of the *NATO Code of Best Practice (COBP) for Command and Control Assessment*. Although it is very clearly stated that tools are only as good as the data – and therefore beside the processes of verification, validation, and accreditation (VV&A) for tools, a processes of verification, validation, and certification (VV&C) for data are needed – the requirements for data are not clearly articulated but rather scattered through all of the COBP.

The revised COBP acknowledges the intrinsic value of data by providing Data treatment in its own chapter. Furthermore, the concept of meta data, i.e. “information about information,” is introduced. Additionally, data domains, data sources, and data classes are defined. The overall objective is to establish a new view of data as a strategically valuable entity in its own right. Operational requirements and technical constraints are formulated to enable the establishment of a common data infrastructure thereby providing for the long-term reemployment of data once captured.

However, the revised COBP is still focussed on the domain of conducting a single operational analyses (OA) study. The overarching objective of this paper is to allow the reader to realise the full spectrum of the potential benefits of data standardisation, aligned data engineering processes for the broadening OA community, and the long term goal of an established common data infrastructure, the scope must be broadened beyond the limits of a single study.

A commonly agreed upon data infrastructure does not exist today thereby limiting the utility of data across a wide range of multi-disciplinary studies. The technical objective of this paper is to propose some techniques for managing data in the near term that will allow for the transition to a common methodology of data management resulting in data utility across multiple studies in the future. As more and more data becomes available in open sources, standards must be formulated that will allow for that data to be found, manipulated, used, and stored efficiently. Application of these standards will require a new role in the study team, that of the data engineer, who is not only responsible for the already well known data collection process, but also for the harmonization of all efforts connected to the data, including the evaluation of existing data and meta data as well as updating the meta data for use both within the study and ensuring it is available in usable format for future studies.

To summarise the objectives, this paper focuses on the requirement for and proposes processes of data management at the macro as well as at the study level, which will allow for the future re-use of the data across multi-disciplinary study efforts. To this end, the importance of meta data modelling, the role of the data engineer and the methodologies to be established for a future common data infrastructure will be described in more detail than it is in the revised COBP.

To reach these objectives, the following topics will be discussed:

- Section two provides a practical example highlighting the role of data within an OA study that will be used to demonstrate the necessity to cope with the overarching issue of this paper.
- Section three provides the documentation requirements for data consistency and data traceability within and beyond a single study and the necessity to support data reuse by application of appropriate meta data standards are shown.
- Section four explores the new role of the data engineer on the study team.

- Section five introduces technical constraints and applicable technologies to establish the proposed common data infrastructure.
- Section six summarizes the observations and provides some recommendations for near term implementation that will complement the new data section in the revised COBP.

2.0 A PRACTICAL EXPERIENCE ON THE ROLE OF DATA WITHIN A STUDY

This section depicts some insights and lessons learned from participation within an ongoing NATO feasibility study.

2.1 The NATO Active Layered Theatre Ballistic Missile Defence Feasibility Study

A feasibility study is a critical step in the NATO Phased Armaments Procurement System (PAPS). Essential to the transformation of a NATO Staff Target to a NATO Staff Requirement, it must provide a detailed architecture design and operational performance standard for the project definition phase. The operational analysis conducted in such a study has to be documented thoroughly. Recent national and NATO studies and study results have to be taken into account and should be reused wherever possible. Decisions and associated analyses supporting those decisions have to be documented in a traceable form and should be reusable in follow-on steps of the NATO PAPS.

The example case used here is the ongoing NATO Feasibility Study on Active Layered Theatre Ballistic Missiles Defence (ALTBMD) being conducted on behalf of the NATO Consultation, Command and Control Agency (NC3A). NATO is funding two contracts for the NATO ALTBMD Feasibility Study and the NC3A has invited two consortia of international companies to conduct the feasibility study in parallel. The consortium, from which the examples used in this section have been drawn, combines leading US and European studies and systems houses committed to develop a viable long-term TMD program for NATO: SAIC (US), Boeing (US), Diehl (GE), EADS (FR), IABG (GE), QuinetiQ (UK), and TNO (NL).

Many aspects of the revised COBP are reflected in the ALTBMD feasibility study. For example, the list of deliverables can be mapped quite easily to the products of an OA study as defined in the revised COBP. Also the methods described in the study dynamics section can be clearly observed. However, this paper will limit itself to those examples derived from participating in the study group relevant to the data section of the COBP.

The ALTBMD Feasibility Study fits in a logical series of NATO study efforts evaluating the military necessity of theatre ballistic missile defence. In 1993, the NATO Council approved the Conceptual Framework for Extended Air Defence followed in 1999 by the refined NATO Air Defence Committee Policy Paper, which further develops concepts for Extended Integrated Air Defence (EIAD). All of this work was supported by respective OA studies and the related data was used to support the ALTBMD study findings.

In addition to the NATO studies, a number of national studies have dealt with related issues. For example, the US Ballistic Missile Defence Organisation (BMDO) is a source for a number of significant analyses that have been previously accomplished. Further, in Europe a lot of work has been done, e.g. within the French-Italian SAMP/T programme. Additionally, information can be found in a number of the weapon system programmes themselves, among others the Theatre High Altitude Area Defence (THAAD) programme, the Medium Extended Air Defence System (MEADS) programme and the respective PATRIOT programmes. These limited examples highlight how the efficiencies gained from re-using data from existing sources can provide a rich base for a study effort.

Within the ALTBMD Feasibility Study additional operational analyses are being conducted. These analysis tasks deal with the vulnerability and the survivability of systems, new details in the engagement process of enemy ballistic missiles, the derivation of engagement models for missiles carrying sub-ammunition including nuclear, biological and chemical options, and more ALTBMD related issues. In addition, costs and logistics evaluations are adding their part to the whole study result.

At the end of the efforts, an architecture proposal and inputs for the NATO Staff Requirements will be derived using a variety of different simulation systems and other OA tools – including the TMDSIM, EADSIM and EADTB. Consequently, three requirements have to be fulfilled within the feasibility study:

- The study results of legacy studies from the participating nations and related companies must flow into the actual study design. In addition, the detailed findings of the tasks dealing with vulnerability, ammunition, kill probabilities etc. must eventually find their way into the higher aggregated simulation experiments that will be conducted to evaluate the efficiency of the ALTBMD architectures. Automated tools to convert the data into the needed data formats as well as procedures to assure the data flow would have made the task easier, however, due to the lack of common standards this effort had to be conducted mainly manually.
- As the different tasks of the study all use their own tools and models, the traceability of data is essential. Every data element should be documented, identifying which other study tasks or former studies are related to it and in what form.
- The results of the study – not only in form of a recommended ALTBMD architecture but also all interim steps, detailed results of sub-tasks, evaluated alternatives, etc. – will be reused in the envisaged follow on procurement process. The ability of the data to be effectively reused will depend in large part on how well it is documented in this study and the methods of archiving.

As a result of these requirements, the study team determined that it was necessary to agree on a set of common data standards which would enable the international participants in the study to store and exchange data in a common information repository. The use of the NATO Consultation, Command and Control System Architecture Framework [NATO 2000] helped in structuring the efforts. How this was done can be found in the Simulation Interoperability Standards Organisation (SISO) paper of Adshead, Kreitmair and Tolk [Adshead et al. 2001].

It goes beyond the scope of this paper to detail the solutions used by the NATO ALTBMD Feasibility Study team. However, the role of data within this study can be seen as prototypical for extensive OA study embedded into a greater context of recent, parallel and future studies. The lessons learned from this experience will be summarised in the next subsection.

2.2 Lessons Learned supporting a Common Data Infrastructure

The experiences from the ALTBMD study as well as other similar studies demonstrate the necessity of common standards to support the processes of obtaining, tracing, documenting the changes to, transforming or processing data. These common standards inextricably lead to the need for a special tool that will facilitate these data handling requirements and when implemented will result in reusability of the initial study results in follow-on phases of the current study and for future study efforts.

While the study management team collected and delivered a data package at the beginning of the ALTBMD Feasibility Study that was more complete than previous studies, it nonetheless comprised only a fraction of the data required for the execution of the study. The additional data required had to be obtained by extensive research including mining of the Internet, reading through available recent studies, analysing the input data for the simulation systems and tools that had been used before, etc. Data not only had to be found, it also had to be harmonised within the study team. All these efforts were mainly based on the engineering judgement of subject matter experts (SME's).

Each task group then had to transform the data into the input data needed for the application of tools and models to be used. After the tools and models had processed the data, the results had to be presented to the study team and subsequently had to be delivered to other task groups who needed the results as input parameters (data) for their respective tools and models. Since no common data repository existed, the technical challenge of the required data format transformations and aggregation was exacerbated by the necessity to establish efficient procedures to insure data consistency between the different task groups. To be able to do this, data traceability from the sources through the transformation and aggregation processes had to be assured.

The applicability of the study results and the reusability of the respective data also had to be assured. In the feasibility study this was especially challenging since the transformation of the data from OA study results to operationally usable study data as well as retaining it for later use within the procurement process for consultation, command and control systems had to be assured as well.

As no universally accepted standards were available to support these efforts, a significant effort went into the evaluation and definition of study specific processes to assure that the needed results were obtained. However, even if these developed solutions do become a de facto standard for future NATO ALTBMD studies, a common data infrastructure accompanied by robust technical support will be required to facilitate the execution of the feasibility study significantly. Additional harmonisation will also be required to insure the transparency and usability of the OA study findings in the procurement phases.

The following sections will show what additional efforts can be undertaken to facilitate such data requirements, especially in the context of embedded studies.

3.0 DOCUMENTING DATA USING META DATA

As is demonstrated in the example above and as discussed in the revised COBP data section, after the data requirements are defined three phases for its use within a study can be identified

- Data must be obtained
- Data is used
- Data is delivered

Figure 1 shows the data flow within as well as beyond an OA study including seven steps that will be defined within the descriptions of the three phases.

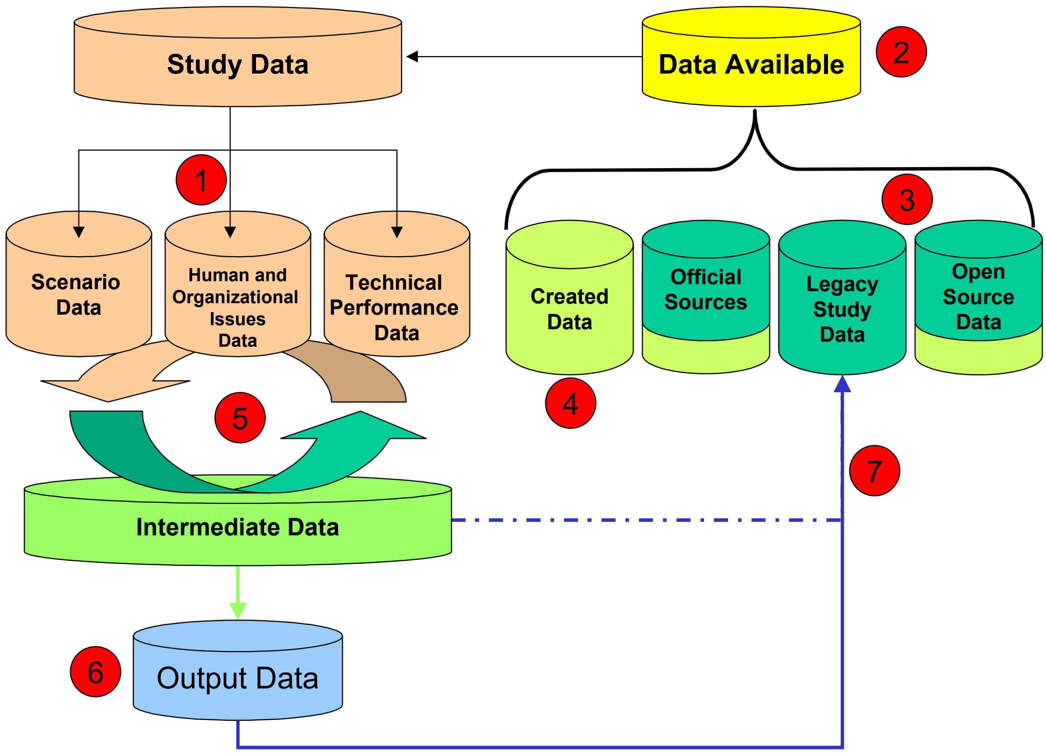

Figure 1: Data Flow within and Beyond an OA Study.

3.1 Obtaining Data

The revised COBP defines four categories of data sources.

- Official Sources are sources such as military databases, other governmental data, data owned by the United Nations, etc.
- Open Sources are data sources that are neither influenced nor controlled by the customer, such as commercial producers (e.g. Jane's) and the Internet.
- Legacy Study Results are data sources derived from other studies conducted by the OA/OR community.
- Finally, when no other means to get the necessary data is available due to the nature of the data requirement or other study constraints data may be estimated by Subject Matter Experts.

Already at each step of the obtaining process, data must be documented to ensure the traceability of results, communicate any constraints connected to the data, and describe any special concerns or requirements for validity, etc. For each data element, the source has to be included in the meta data. If the meta data is not available for the source itself, it should be derived as accurately as possible for each data element or coherent group of data elements. At a minimum the source, reliability of the source, constraints such as models and tools used for processing, title of study, reference to the Internet page should be documented.

To summarise, within this phase, the data have to be defined first (step 1), then the available data has to be checked for consistency and completeness (step 2). Using the various data sources, the data package needed for the study is prepared (step 3), including estimation of not otherwise obtainable data (step 4).

3.2 Data Use

The use of data within the study can be divided into sub-steps that can be of fractal structure within the study itself. First, generally the data obtained must be transformed and aggregated to be useful as input data for a tool or model to be applied in the context of the study. The transformation and aggregation processes of the input data must be documented. As a minimum, the traceability from the obtained data to the input data has to be assured by the meta data documentation allowing the study team to re-evaluate all results connected to input data that is changed during the conduct of the study.[1]

By applying tools and models, new data is produced. For these data elements, the tool or model used to provide them as well as the data being used to drive the tool or the model have to be captured in the accompanying meta data. It is not sufficient just to track the tool or model used, even if it is a previously verified, validated and accredited model, since the input data is important for the validity and reliability of the results as well. This must be accomplished for the entire system for each use.

In figure 1, these processes are covered by step 6: data use and transformation within the study.

3.3 Data Delivery

When the input and intermediate data is finally transformed into data supporting the delivered study result the underlying assumptions, constrains, etc. must be documented. The transformation of input and intermediate data is normally accomplished by interpreting the measure of merits to evaluate the essential elements of analysis (e.g. critical questions, critical operational issues, etc.). In all cases in order to ensure that future analysts are able to evaluate the usability of the study results (data) for their studies the underlying assumptions, constrains, etc. have to be sufficiently documented for them to be able to make value judgements regarding data utility.

The same should also be true for the interim results of a study since it is possible that they may be valuable input parameters for future studies as well, although they may just be a by-product of the ongoing OA effort.

In figure 1, this is covered by step 6 (preparing the data for the study report) and step 7 (preparing intermediate and output data for future re-use).

Finally, it is worth thinking about “sanitised” versions of the study results. In the case of classified studies it would be valuable if unclassified insights that could be valuable inputs for the broader OA community could be collected. The accompanying meta data should then contain the reference to the classified study to assure the accessibility in case of need.

In summary, the use of meta data modelling not only enables efficient data traceability and delivers the needed documentation within an individual study, it is also a requirement for efficient data reusability among different studies. Meta data comprises all information about the data needed to search for and evaluate its applicability for a given study purpose.

4.0 DATA ENGINEERING

Until recently, the concerns about data could generally be limited to developing a data collection plan at the beginning of the study. As the preceding three sections illustrate, data’s importance to both an

[1] E.g., in the ALTBMD the vulnerability of a special missile type changes due to some technical break through in the engagement phase, all simulation results using the old vulnerability model (including former studies) have to be at least re-evaluated. In some cases it may even be possible that old study results are not valid any longer.

individual study and to the body of corporate knowledge is increasing daily. Consequently a new sense of professionalism has to be adopted by the OA community concerning the handling of data. The definition of a new role within the OA community as a whole and in the study team in particular is the logical consequence – the data engineer.

The data engineer is responsible for the overall management of data within the context of an individual study and for ensuring that it is properly collected, tagged and archived for later use. Within a specific study effort, the data engineer is responsible for obtaining the data, evaluating the meta data with concern to the study needs, transforming it to meet the tool and model requirements, documenting the data as it is transformed throughout the study effort, conducting meta data modelling to handle the meta data for the study as well as for future studies and for the data and information exchange between the study team and the OA community.

A data engineer is obviously much more than a data collector, although this is still an important task for him. The data engineer must be able, however, to "dig for the data" within the full spectrum of available sources. To effectively do so, this person must not only understand the data itself, but he also must be aware of the macro level data needs of the study. Among other things the engineer must be able to identify the needed level of reliability, acceptable sources, needed formats, fidelity requirements, possibilities for aggregations and deaggregations, limits of data transformation, etc. The data engineer must be able to understand and analyse information repositories of other research communities as well as using the principles of Information Resources Dictionary Systems (IRDS) to map the available data to his own needs.

The data engineer can be seen as the bridge between the OA study team and the data available. The engineer's job is to assist the study team in finding and obtaining needed data "wherever and in whatever format it should be" to enable them to conduct the study. The data engineer might be compared to the expert within the response cell (RC) of a computer-assisted exercise (CAX) – he must understand the needs and plans of the study team as the RC expert must understand the needs and procedures of the training audience. The data engineer must also know where and how to obtain the data and transform it to the needs of the study team just as the RC expert has to generate the appropriate simulation system inputs from the commands of the training audience.

The data engineer will be supported by new data management tools like improved search engines, meta crawlers, etc. analogous to the way software support, like automatic interfaces between the simulation system and the command and control system, facilitates the work of the RC expert.

5.0 THE COMMON DATA INFRASTRUCTURE

As pointed out before, one of the main problems the broadening OA community is faced with is the heterogeneity of data sources being used. This is not a new problem. The necessity to agree on common standards is one of the driving factors for the Simulation Interoperability Standards Organisation (SISO). Similar recommendations can also be found within the Military Operations Research Society (MORS). The following citation is taken from the conclusions of the MORS Data Working Group, and although it is over ten years old it is still valid:

> *"The single most important activity ... would be a concerted effort to get all members of the team to see the same battlefield through a common engineering approach, shared data-bases, common tool sets, and a network of all players. It was consensus of the working group that one of the most critical needs was to produce an overt structure that linked all members of the data/modelling team. ... The data sets must be clearly described and understandable to a user with subject matter knowledge ... The data description must be robust enough to inspire user confidence in the data."* [DWG 1988]

As pointed out in the COBP and in previous sections of this paper, the overarching objective regarding data is the seamless sharing of information between:

- the study team members
- the evolving phases of the study
- the models and tools used within the study
- the study team and the broader OA community (reusability).

Documentation of data (including validity and reliability of sources, constraints, etc.), consistent recording of data transformation and enabling data re-use of both the interim and final study findings by future studies are the imperatives behind the drive to establish a common data infrastructure. The technical feasibility of such a common infrastructure has already been proven in the domain of electronic commerce. The obvious similarity between the applications of Collaborative Product Commerce and the Support of Combined and Joint Military Operations Other Than War has been shown (e.g. Krusche and Tolk 2000). The necessary technologies are based on the idea of efficient shared data management using the same procedures and meta data models to document the findings of these processes. The common data infrastructure has to be able to store the data as well as the meta data in a well defined – and preferably standardised – manner. Fortunately, a mature international standard is already established that can by applied to serve the OA community's need – an Information Resource Dictionary System (IRDS). The main ideas of an IRDS are defined in the ISO IRDS standard [ISO 1990]. The main purpose of an IRDS is to support data administration and data management. A NATO application example can be found in [NDAG 1999]. Another existing source of collected data is the US Defence Modelling and Simulation Office's (DMSO) Authoritative Data Source (ADS) Project. The ADS project catalogues all M&S relevant data/knowledge sources within the US Department of Defence and the Modelling and Simulation community at large.

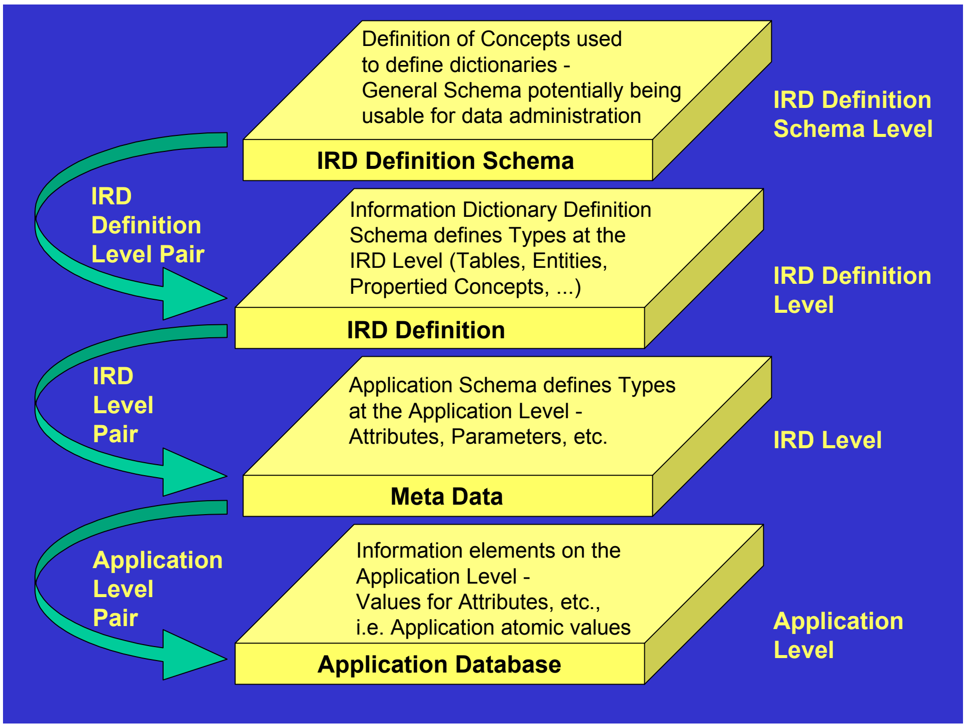

Figure 2: Levels of Information in IRDS.

An IRDS can be defined as a software system comprising and managing the information resource dictionary in which the information of all participating applications will be recorded. It has been shown how this idea can be extended in the way that the IRDS can also be used to support the federate integration process of the high level architecture (HLA) by making the efforts of the data standardisation community usable for the federation builders.

The IRDS framework defines four levels of information shown in figure 2. Each level in the framework has a sub-level that consists of the definition of the information contained in its respective sub-levels. Therefore, the use of the ISO IRDS framework allows a gradual introduction of concepts and methodologies from the most abstract form down to most concrete and tangible application and implementation requirements. Thus, the different methodologies of relational data modelling using IDEF1X, and object oriented modelling using UML are nothing more or less than different concepts within the IRDS on the respective level. By storing the respective data management results also within the IRDS, the IRDS builds the kernel for a common data infrastructure fulfilling the needs as stated before. If the needed data is available in whatever format using whatever data modelling methodology, it can be found and transformed in standardised manner from the IRDS respective the common data infrastructure.

In addition to these technologic solutions, data management is necessary. Within NATO, data management is defined as planning, organising and managing of data by defining and using rules, methods, tools and respective resources to identify, clarify, define and standardise the meaning of data as of their relations. This results in validated standard data elements and relations, which are going to be represented and distributed as a common shared data model. As this definition indicates and as this paper and the revised COBP support, efficient data administration is an information intensive process involving a wide range of participants with impact and implications that extend well beyond the scope of a single study. The data required is generated, managed, and used by a large number of participants in the multi-disciplinary and multi-national study team as well as by members of the broader OA community. Every entity delivering an application to participate in multiple federations – consuming and delivering data from and for the federation – has to be involved in the process of data management. Effective collaboration between all participants in the process of establishing a common data standardisation is essential in order to gain and preserve a common understanding of shared data. Therefore, an essential purpose of data administration activities must be to achieve an integrated data standard that will facilitate the broader needs of the OA community for data use/reuse.

It should be pointed out that the requirements for aligning the data management procedures of the OA community – and in many cases even to make the necessity of data management and documentation clear to the decision makers – are at least as challenging as the technical ones. However, the benefit for the OA community is expected to be very high.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The Data Section within the revised COBP has been a valuable addition to the first version. It will help to make the analysts, users and the decision makers aware of the strategic value assigned to re-usable and shared data. The necessity for a common data infrastructure – accompanying other repositories like a model and tools repository as recommended in the NATO Long Term Scientific Study on Human Behaviour Representation [NATO 2001] – is becoming obvious.

As the OA community is broadened to take into account human and organisational issues in addition to technical performance as part of the equation to evaluate the military socio-technical system, the existing common basis of OA and modelling and simulation must likewise be broadened to include the research domains of psychology, sociology and other human sciences. It is essential to co-ordinate standardisation efforts as early as possible to avoid repetitive work and to enable information sharing across the broadened OA Community.

A common data infrastructure using a standardised way to use, modify and record data elements is a necessary requirement for efficient and continuously interoperable information sharing within the broad OA community. Success in establishing such a data infrastructure through the application of the techniques outlined in the revised COBP for current and future studies will contribute greatly to assuring the success of future joint and combined efforts across the full spectrum of military operations.

7.0 REFERENCES

Following reports and articles are referenced in this paper:

[Adshead et al. 2001] S. Adshead, T. Kreitmair, A. Tolk: "Definition of ALTBMD Architectures by Applying the C4ISR Architecture Framework", Paper 01F-SIW-112, Proceedings of the Simulation Interoperability Workshop Fall 2001, Orlando, Florida, September 2001.

[DWG 1988] Report of the Data Working Group, Simulation Technology-1997 (SIMTECH-'97), US Army Engineer Studies Centre, March 1988; Monterey, California, June 1988; National Defence University, November 1988. (DTIC: ADB 152 051 and ADB 152 052 ADB 152 053).

[ISO 1990] ISO Standard IS10027: IS10027:1990, "An Information Resource Dictionary System (IRDS) Framework", 1990.

[Kendrick et al. 1999] David E. Kendrick, Jack Sheehan, Lana Eubanks McGlynn, Mike Hopkins: *Authoritative Data Sources for use in DoD Modelling and Simulation*, Proceedings of the Simulation Interoperability Workshop Fall 2001, Orlando, Florida, Fall 1999.

[Kendrick et al. 2000] David E. Kendrick, Jack Sheehan, Mike Hopkins, Katherine Rowe: *Authoritative Data Sources: Enhancements to Satisfy Future Needs and Long Term Maintenance Requirements*, Proceedings of the Simulation Interoperability Workshop Fall 2001, Orlando, Florida, Spring 2000.

[Krusche and Tolk 2000] Stefan Krusche, Andreas Tolk: "Information Processing as a Key Factor for Modern Federations of Combat Information Systems", NATO/RTO Information Systems Technology Panel (IST) Symposium "New Information Processing Techniques for Military Systems", Istanbul, October 2000.

[NATO 2000] NATO Consultation, Command and Control Board (NC3B): "NATO C3 System Architecture Framework", AC/322-WP/0125, Brussels, November 2000.

[NDAG 1999] NATO Consultation, Command and Control Board (NC3B), Information Systems Sub-Committee (ISSC), NATO Data Administration Group (NDAG): "Feasibility Study for the NATO C3 Information Resource Dictionary System (NC3 IRDS)", AC/322(SC/5-WG/3)WP4, Brussels, September 1999.

8.0 LIST OF ACRONYMS

Following acronyms and abbreviations are used within this paper:

ALTBMD	Active Layered Theatre Ballistic Missile Defence
C3	Consultation, Command and Control
COBP	Code of Best Practise
EADSIM	Extended Air Defence Simulation
EADTB	Extended Air Defence Testbed

EEA	Essential Elements of Analysis
EIAD	Extended Integrated Air Defence
HLA	High Level Architecture
ICAM	Integrated Computer-Aided Manufacturing
IDEF1X	ICAM Definition for Data Modelling
IRDS	Information Resource Dictionary System
MEADS	Medium Extended Air Defence System
MOE	Measure of Effectiveness
NC3A	NATO C3 Agency
NC3B	NATO C3 Board
NDAG	NATO Data Administration Group
NSR	NATO Staff Requirement
NST	NATO Staff Target
OA	Operational Analysis
PAPS	Phased Armaments Procurement System
SAMP/T	Sol-Air Moyenne-Portée/Terrestre
SISO	Simulation Interoperability Standards Organisation
SIW	Simulation Interoperability Workshop
THAAD	Theatre High Altitude Area Defence
TMDSIM	Tactical Missile Defence Simulator
UML	Unified Modelling Language

AUTHOR BIOGRAPHIES

Mark R. Sinclair is the Advanced Programs Manager for Veridian's Simulation and Integrated Solutions Group. He participated as a member of the US delegation to the NATO SAS-026 Panel charged with revising and extending the *NATO Code of Best Practice for Command and Control Assessment*. He is a retired Lieutenant Colonel in the United States Marine Corps where he served as a Command and Control Systems officer for more than twenty-five years. His operational experience includes Vietnam, Central America, Haiti and the Balkans.

Andreas Tolk is Senior Scientist at the Virginia Modeling Analysis and Simulation Center (VMASC) of the Old Dominion University, Norfolk, VA, since April 2002. Before, he was Vice President for Land Weapon Systems at IABG mbH in Ottobrunn, Germany. He participated as a member of the German delegation to the NATO SAS-026 Panel. Within the referenced NATO Feasibility Study, he was responsible for Command and Control Architecture Definitions. He is an expert for Command and Control Systems and Simulation Systems Interoperability issues.

An Enemy Within the System: Illustrative Examinations of C2 Questions using Distillations

Dr. Gary E. Horne
The MITRE Corporation
3300 Russell Road
Quantico, VA 22134
USA
[1] 703-784-6007

hornege@mccdc.usmc.mil

Dr. Henrik Friman
Swedish National Defense College
P.O. Box 27 805
115 93 Stockholm
SWEDEN
[46] 8-788-9343

henrik.friman@fhs.mil.se

ABSTRACT

The events of 11 September have motivated a great deal of research within the United States Marine Corps Combat Development Command modeling effort called Project Albert. The beginnings of one such effort will be described in this paper. Distillation models are used by a collaborative team of researchers from the United States and Sweden to begin to examine questions related to homeland defense. Two basic types of illustrative scenarios are examined in this paper. In the first the enemy blends within a general population, while in the second the enemy is actually embedded in the force. The paper describes the results of base case scenarios and excursions with different C2 measures of effectiveness using the NATO Code of Best Practice for C2 Assessment as a guide. The distillation models ISAAC and Socrates were run many times within the process of Data Farming to support the risk and sensitivity analyses described in the Code. Excursions examined in the research include changes in the nature and number of enemies, commander trust, communication intervals, and communication ranges. Results presented are preliminary, however, the robustness of various C2 structures across these changes in the system is the intended focus as this research continues.

Key Words: *Data Farming, Distillation Models, Homeland Defense.*

1.0 INTRODUCTION

The United States Marine Corps Combat Development Command Project Albert seeks to advance the state of the art in modeling, simulation, and analysis of questions important to the United States Marine Corps and collaborators around the world. These questions are relevant to C2 doctrine, force structure, tactics, techniques, and procedures for the asymmetric environments, the process involved in course of action development, and many other important areas. In the area of C2, collaborative arrangements between Project Albert and researchers in Sweden are emerging because of shared interests and synergistic capabilities residing in the defense establishments of the two countries.

Project Albert exploits advances in high performance computing power, data perception techniques, and new and existing methods of simulation and decision support. It attempts to capture three important phenomena in the context of combat modeling: nonlinearity, intangibles, and co-evolving decision landscapes. Project Albert

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distillations (fast, easy to run models which distill the essence of a particular question) may provide hope in modeling and analyzing non-conventional threats. These distillations are used in conjunction with the Data Farming methodology to explore possibility spaces using many, often millions of, runs. This large volume of data along with the ability to sift through it quickly and efficiently and grow more data in areas of interest is a fundamental idea being pursued within Project Albert that may help answer the questions at hand. Combined with current methods, this process may produce insights not achievable with the current system of combat models and analysis tools alone.

In this particular paper, we describe the use of Project Albert ideas within the philosophy of modeling C2 described in the NATO Code of Best Practice for C2 Assessment in a beginning look at two different meanings of "an enemy within." One is an enemy within the population and the second is an enemy within the force itself. In this first case, having an enemy in the midst of a population and not easily recognizable is an age old phenomena that was starkly brought to the forefront on 11 September. Secondly, the phenomena of having insiders or traitors has been discussed since the age of Sun Tzu. But in the scientific field of command and control today we are still lacking a deep understanding of the nature of an enemy within the system. It is reasonable to assume that an enemy within the system will degrade the system effectiveness, and by better understanding the nature of this situation we hope to begin to develop a deeper understanding of the consequences of having enemies within the organization.

2.0 EXAMINING C2 QUESTIONS USING THE NATO CODE OF BEST PRACTICE

At the outset we would like to state three points about our C2 research. First, we would like to stress that this paper describes research that is just beginning and as such the "results" are not findings so much as guidance for future research on C2 questions. Thus the reader will see that the research is characterized as "illustrative" throughout the paper. Second, it should be noted that the data farming of distillations emphasized in this paper is not meant to give the final answers to C2 questions, but to be part of an overall process called Operational Synthesis. This process (described in more detail in Maneuver Warfare Science 2001) uses models and simulations at different levels of verisimilitude and various methods of operations research to attempt to get at the answers to questions. Third, as both a nascent and multinational research project, the application of the NATO Code of Best Practice (CoBP) for C2 Assessment is particularly appropriate for this research.

The guidance contained in the NATO CoBP is intended to assist research teams, especially as research is beginning. Particularly germane to this research is the emphasis on iterations through the assessment and we consider this research to be just the first iteration used to scope the questions at hand. Also, the questions and methods are structured so as to encourage creativity and lateral thinking as recommended by the CoBP. Finally distillations and the methodology of Data Farming are used. Because distillations are fast running models they allow for many runs and an exploration of a large landscape of possibilities. And data farming allows for the iterative exploration of areas of interest that the researcher thinks may shed light on the questions at hand. Together distillations and the data farming of distillations allow for the scoping of the space of possibilities as encouraged by the CoBP as well as a guide to more focused C2 assessments as recommended in the CoBP.

The C2 questions at hand include the effects of the number, density, and range of sensors out to identify the enemy within, as well as the range that information received can be communicated. Another question area involves information assurance with an examination of the effect of different "trust" levels, i.e. how much the force believes the information communicated. The effect of a "false alarm," or an agent that is incorrectly identified as one with the intention of committing a terrorist act is also examined. Questions related specifically to an enemy within the force itself were examined by varying the competence level of one of the agents. Research in this area at this stage is quite limited and the intent is to extend it to different levels of command, different numbers of enemies, and different characterizations of the enemy within. Of course, the interaction effects of all of these factors and others with C2 capabilities is something that will be explored as the research continues using Data Farming with distillations within the CoBP philosophy.

3.0 ENEMY WITHIN THE POPULATION

The first case of an enemy within that we will examine is when the enemy is blending into the general population in some way in order to eventually do harm against a target of high value located within the homeland of the general population. Obviously the World Trade Towers and the Pentagon qualify as high value targets of this kind and the attacks on these places motivate this research. Our objective in this paper, however, is not to model the events of 11 September specifically or of any particular real world event that has occurred. Our focus in this research is to examine questions related to C2 in a generic homeland defense context to develop a deeper understanding of what it means to have an enemy within the system, help guide further research in this area, and eventually perhaps help decision makers make choices resulting in more effective homeland defense.

We begin by examining a single enemy that tries to avoid detection and reach a high value target. Specific questions related to C2 are: What is the effect of different levels of agents in the general population with the ability to detect the enemy?, What is the effect of a second red agent as a distraction on detection of the first?, and What are the effects of sensor range, communication range, and information assurance on blue force ability to stop red from reaching the high value target? We use Data Farming and the distillation model ISAAC to investigate these questions across a variety of changes in both the characteristics of the enemy as well as the blue side, but as research continues, we hope to gain a better understanding of the effectiveness of the blue force in stopping an enemy within the system across a wider landscape of possibilities.

3.1 ISAAC

ISAAC is an agent-based simulation modeling system where the input scenarios can be created and altered quite quickly using a text editor. The underlying methodology driving the distillation is a hard-coded physics-based approach. ISAAC represents agents via three states: alive, injured, and dead. Agent behaviors are determined by personality traits that include propensity to move toward or away from other agents or goals; by intangible factors such as unit cohesion, trust, and aggression; and by physical characteristics which determine the agent's weapon capability, sensor range, and communications range. ISAAC can maintain up to three levels of command and control: a global commander, a local commander, and an individual agent/squad. Up to ten squads can be defined, for which different variable personality and physical parameters can be assigned. Terrain is represented as obstacle blocks which impede movement and shot capabilities, but not line of sight. For a more complete description the reader can refer to Maneuver Warfare Science 1998.

3.2 Illustrative Scenarios

Two closely related ISAAC scenarios were developed for this study. Both scenarios include three major entities: a centralized protective force (blue), a dispersed "civilian" population (also blue), and a single enemy agent (red) that represents a terrorist with the mission of reaching (and thus, in our minds, destroying) a high value target. The second scenario also includes a second red agent that does not go for the target thus representing potential "false alarms." As in all of the work presented in this paper, the reader must remember the illustrative nature of the scenarios, i.e. they are simply dots and results should not be considered in isolation. We are motivated by our desire to understand the effect of civilian sensivity to suspicious or threatening behavior on the ability to stop the enemy. Thus in this work we create notional representations to try to capture the essence of a situation in order to try to add insight to pertinent questions. That being said, in the base scenario the "terrorist agent" is initially positioned randomly in the lower quadrant of the field. This agent seeks to avoid the population and the protective force and attempts to reach the high value target represented by the blue flag. The blue population is distributed evenly over the playing field and the individual agents maintain a random walk around their initial positions. Neither the population or the red agent are given any weaponry. The protective force will pursue the red agent if they are aware of its position and they have weaponry and will stop the red agent if they are within firing range. If a population agent senses the red agent it may communicate the position of the agent to the protective force if the population agent is within communication range. If the red agent succeeds in reaching the goal, it is considered a blue loss while if the agent is killed, it is considered a blue win.

In these scenarios the blue population's sensor range represents the level to which the population has the ability to observe and identify possible terrorist activity. The number and density of the blue population represent the number or portion of the population able to observe and identify. The blue flag (marked as a blue "+" in Figure 1) represents the set of possible high value targets that the red agent may attack. Communication range represents the ability of the protective force to receive terrorist sightings from the population and the communication weight represents the "trust" the force places in these sightings. For this study, several of these parameters were varied to examine the effects communication, training, and trust have on the ability of the blue force to ward off a terrorist attack.

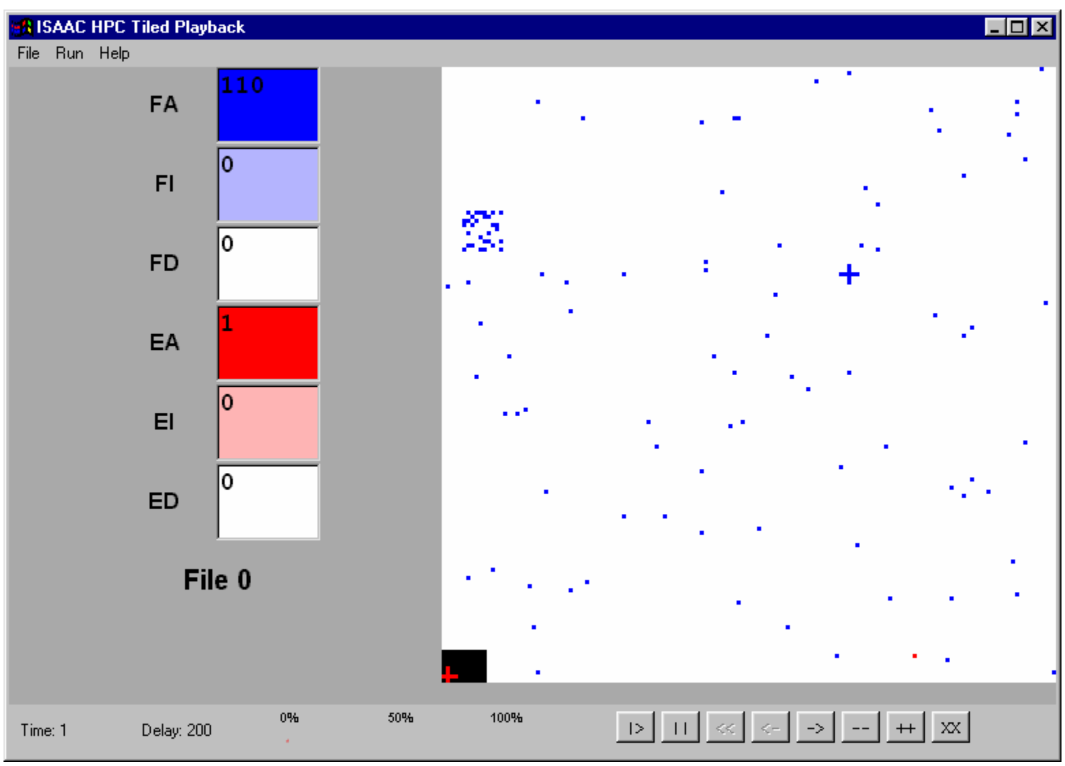

Figure 1: ISAAC Scenario 1 – Single Red Terrorist.

The second scenario (shown in Figure 2) includes a distracting agent or "false alarm." This red agent does not move toward the goal but maintains a random walk which can wander into the sensor range of members of the population. This entity can serve to distract the protective force from the agent who is attacking the goal. The sightings and reporting of this agent can represent either purposeful misinformation or occasional blunders on the part of the population.

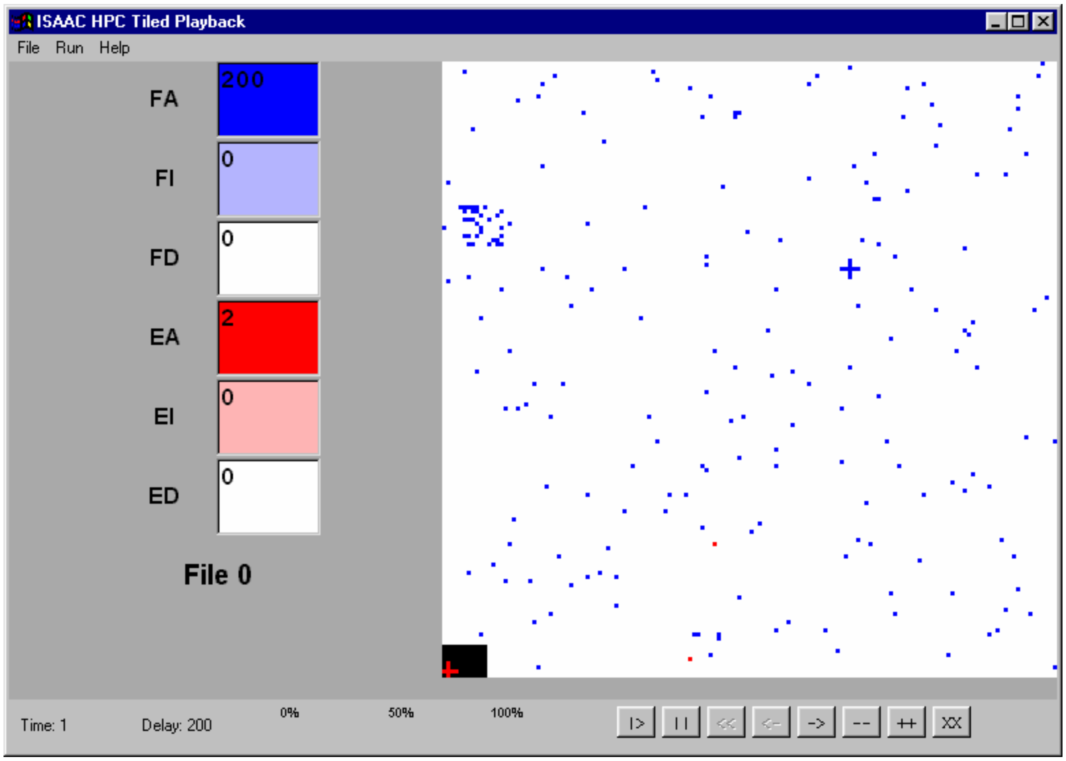

Figure 2: ISAAC Scenario 2 – False Alarm.

3.3 Illustrative Results

A total of more than 300,000 runs of these ISAAC scenarios were executed at the Maui High Performance Computing Center in order to examine the effect of parameter variations on the illustrative scenarios. The following figures present these results as "landscape" plots. The X and Y axis of these plots represent variations in the input parameters of the scenarios. Every combination of input parameter variations was executed 30 times in order to allow examination of the possible statistical variation of the scenario.

Figure 3 shows the effect of an increasing density of "trained" observers within the general population. In this scenario, which has a single red "terrorist" agent, the number of population agents was increased from 40 to 80 and then to 120. The X axis in the plots represents blue sensor range. The Y axis represents blue communication weight. The Z axis represents the "terrorist" agent's effectiveness in reaching the target. Note that as the density of observers increases, the red agent's success rate, in general, goes down.

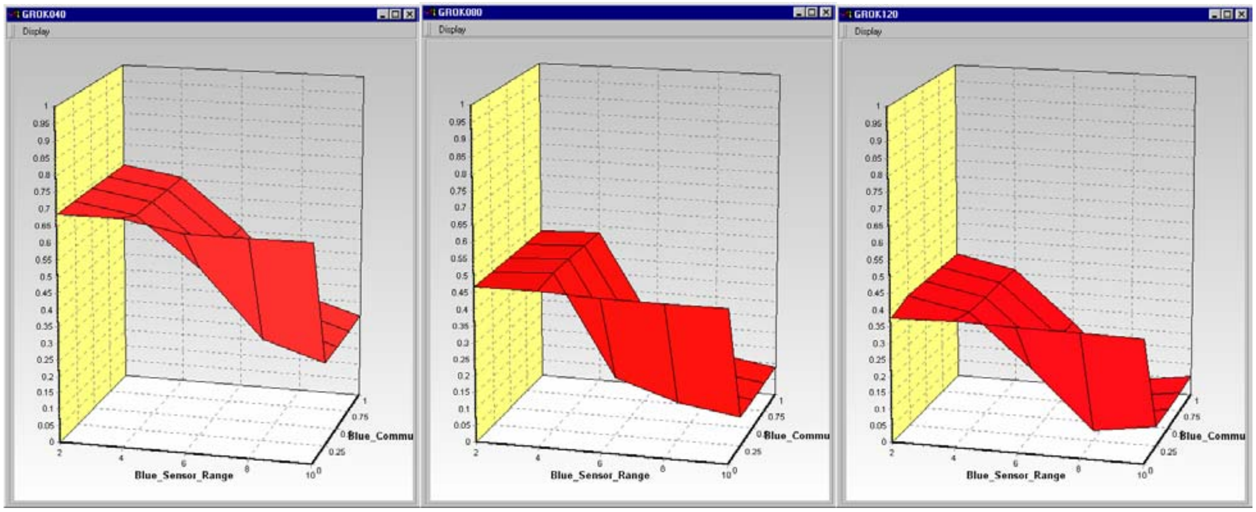

Figure 3: ISAAC Scenario 1 – Population Density Variation.

Figure 4 shows that the "False Alarm" agent has a significant effect on blue ability to ward off the attack on the high value target. In the figure, the vertical axis again represents red effectiveness at reaching the high value target. The top landscapes represent the maximum and the lower landsapes the mean of 30 replications of ISAAC for the given scenario and parameter set. Similarly, Figure 5 shows the more modest impact that increasing the blue population's sensor range has on blue's effectiveness and Figure 6 demonstrates that the communication weight has almost no effect on the red's ability to reach the high value target.

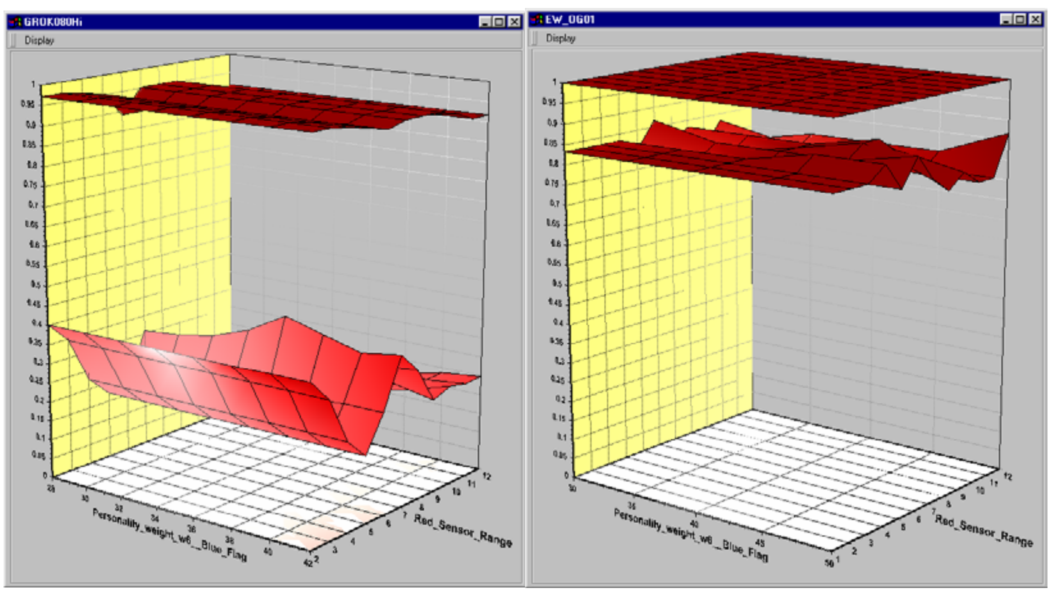

Figure 4: ISAAC Scenario 1 and 2 – Blue Sensor Range = 6.

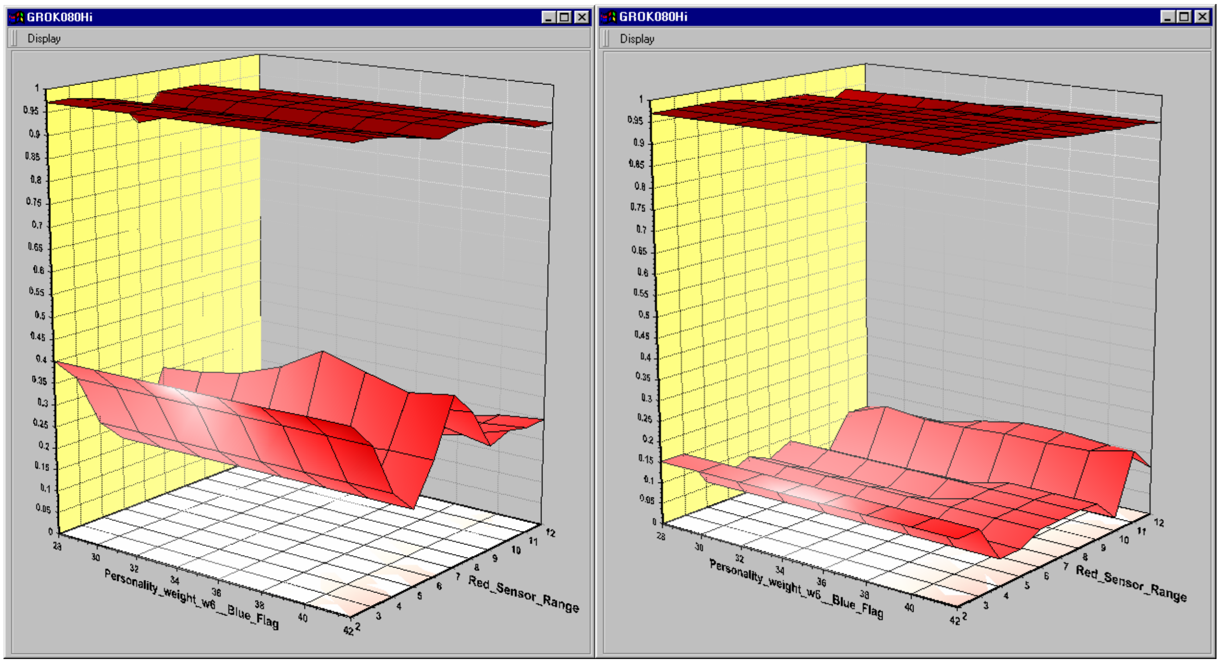

Figure 5: ISAAC Scenario 1 – Blue Sensor Range = 6 vs. 10.

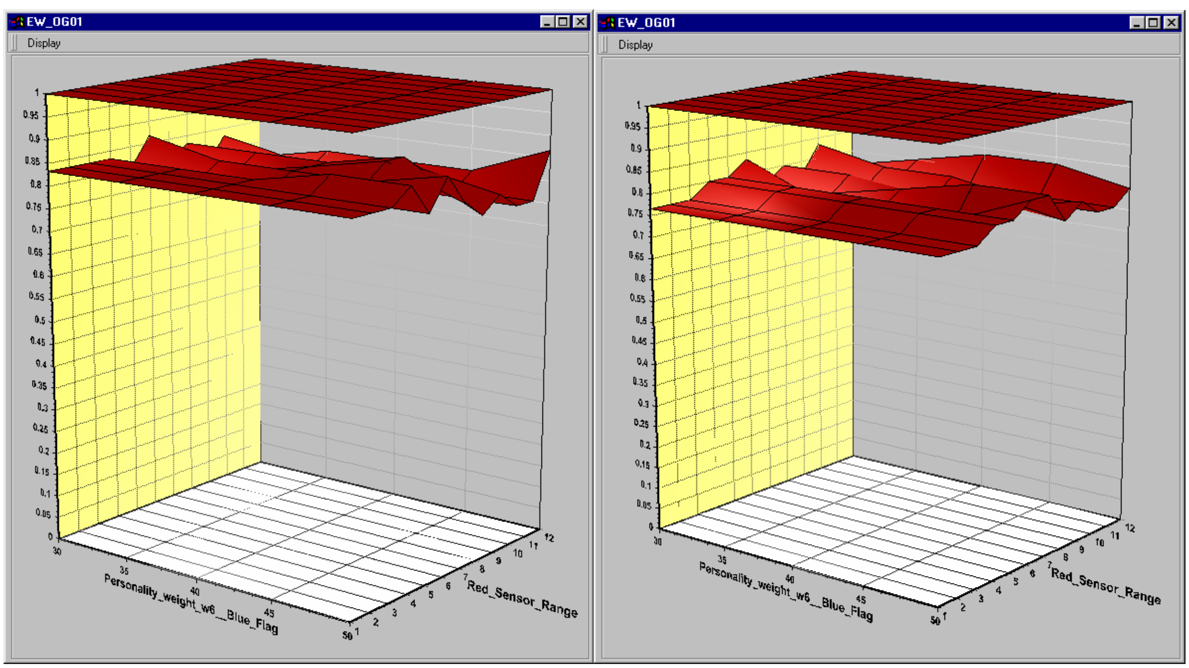

Figure 6: ISAAC Scenario 2 – Blue Communication Weight = 1.4 vs. 0.1.

4.0 ENEMY WITHIN THE FORCE

One of the worst situations a military commander could face is to have an enemy within the force. To have an enemy within a group of trusted ones creates an extremely stressful situation. The fact that this enemy is not visible creates situations where traditional ways of conducting war are not suitable. Through history the literature describes stories about spies and insiders that by their position within an organization could create major damage and chaotic situations, both physically and psychologically. All the way back to the days of Sun Tzu days the common opinion is that having an "agent" placed inside the opposite force creates advantages that potentially gives success for one side and a major disaster for the other.

But today we lack a deep understanding of what it means to have an enemy within the system. Our focus of effort in this research is to explore further the nature of insiders and their role on a system's ability to achieve results, or in other words the degradation of system effectiveness that these insiders may cause. Using Data Farming and the distillation model Socrates we began a series of illustrative examinations in order to investigate the impact of insiders on system effectiveness. We designed a number of different excursions in order to investigate the insider's nature and role. The enemy within the force in this initial work takes the form of degradation of capability, i.e. incompetence. What we examined in this initial work is limited, but illustrative. Further work will include (1) the impact of the number of insiders, (2) the impact of insiders placed within different levels of the organization, and (3) the impact of various levels of robustness of the insiders. In general, as this research continues we will search for a better understanding of *what it means to have an enemy within the system.*

4.1 Socrates

Like ISAAC, Socrates is an agent-based distillation modeling system. Socrates scenarios are developed using an XML editor. Socrates uses a values-driven methodology as its approach. Agents within Socrates are represented as either alive or dead (injured states do not exist in this distillation). There are three levels of command in Socrates. They are the top level commander, middle level leader, and an individual often referred to as a "grunt." Agents can be defined individually and any given number of agents instantiated. Tactical decisions are determined by the agent's position in the command and control structure; by intangible factors such as trust and allegiance; as well as physical characteristics such as weapon capability, sensor range, and communication channels and ranges. Terrain is represented as obstacle blocks which impede movement, however, neither line of sight nor shot capabilities are degraded. More information can be found on the Military Science and the Project Albert websites listed in the references.

4.2 Illustrative Scenarios

Socrates scenarios were developed to examine the effects of the enemy within the system, in this case manifested as incompetence within a hierarchical command and control network. The scenarios were designed to include a single main commander, three secondary commanders, and nine grunts. Two screen shots demonstrating the scenario are included as Figure 7. The initial layout of the scenario is the same in the base case as well as subsequent excursions. The base case is a standard force on force, evenly matched battle of blue against red. There is no high value target, per se, but territory control is the de facto "high value target." Experimental data farming runs were setup to explore the effect "incompetent" grunts have on the outcome by varying the weapon and the sensor of one or more combatants on a single side. Data was collected in three cases: 1) the base case with evenly matched forces, 2) an excursion with one "incompetent" blue grunt; and 3) an excursion with one "incompetent" blue grunt having variable levels of "incompetence."

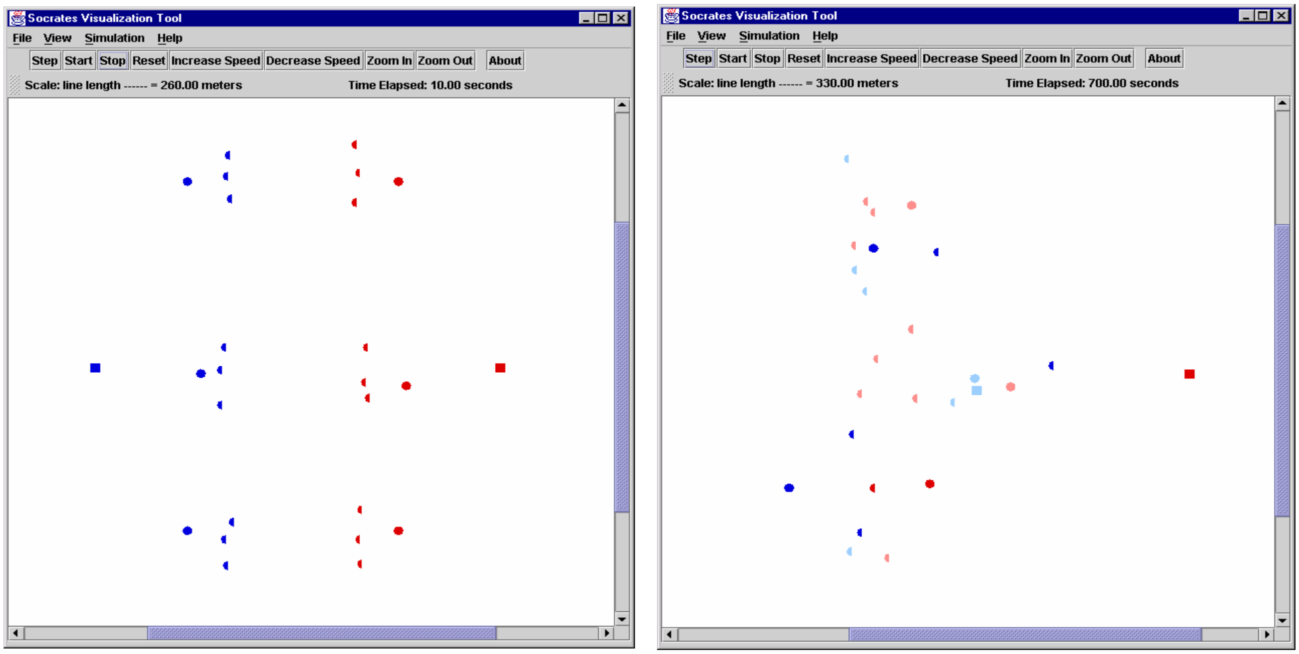

Figure 7: Socrates Scenario at Two Different Time Steps.

4.3 Illustrative Results

For each case, a total of 30 replications per parameter combination were executed at the Maui High Performance Computing Center. In the base case, all blue agents have the same weapon capabilities and sensor range. Red agents also have the same parameter settings as blue, the main difference being tactics. The parameter space under study included the following variations: blue weapon probability of kill (pK) ranged from .001 to .009 by increments of .002, blue weapon range varied from 300 to 700 by increments of 100, and blue weapon radius ranged from 1 to 4, by increments of 1. In the case of an “incompetent” grunt, a single bad blue grunt was inserted into the middle of a tactical formation. This “incompetent grunt” has weapons range of 10.0; weapon radius of 2; and pK of .001. Competent blue grunts have a weapon range of 500, a weapon radius of 2, and a pK of .005. All other blue parameters are the same as in the base case. Red agents also have the same parameter settings as the base blue agents, the main difference, again, being tactics.

Figure 8 represents the data for the base and the “incompetent” case where sensor range is the variable parameter. The plot on the left demonstrates the base case and the plot on the right demonstrates the “incompetent” case. The three landscapes in each plot from top to bottom represent maximum, mean, and minimum red kills over 30 replicates. The data presented in this figure indicate that, as pK settings increase, regardless of weapon range and sensor range, blue’s ability to kill red agents increases on the average. Although the shape of the landscapes for the two cases is slightly different, the means for this particular set of parameter combinations are similar. The same trend is present across all sensor range variations.

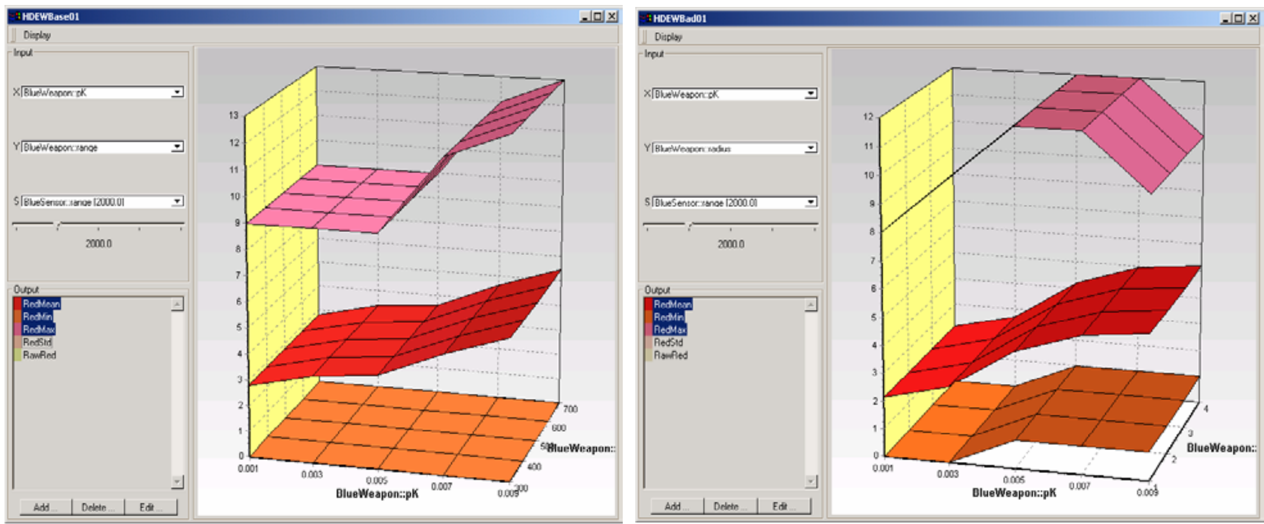

Figure 8: Competent vs Incompetent Case – Variable Sensor Range.

Figure 9 represents the same scenario depicted in Figure 8, only weapon radius is the variable parameter. The outcomes for this combination of settings highlight a different result than Figure 8. As pK settings increase to .005, regardless of weapon range, blue's ability to kill red agents on the average increases, similar to the base case. However, when pK reaches .005, weapon range reaches 500, and weapon radius is 3, average red kills for the "incompetent" case dramatically drop until weapon range increases to 700. The base case results remain consistent with Figure 8. The decrease in red kills for the "incompetent" case could be due to the distance between the incompetent grunt and the two competent grunts on its flanks. One plausible explanation for this dynamic is the relationship between the fields of fire and the "physical" distance between the grunts. When the radius and the range of the weapons is small there is little or no overlap between the grunts' fields of fire. When this occurs, the incompetent grunt receives no help from the flanking competent grunts. As weapon radius and range increase, the overlap among fields of fire increases, allowing the incompetent grunt to receive help from the flanking competent grunts.

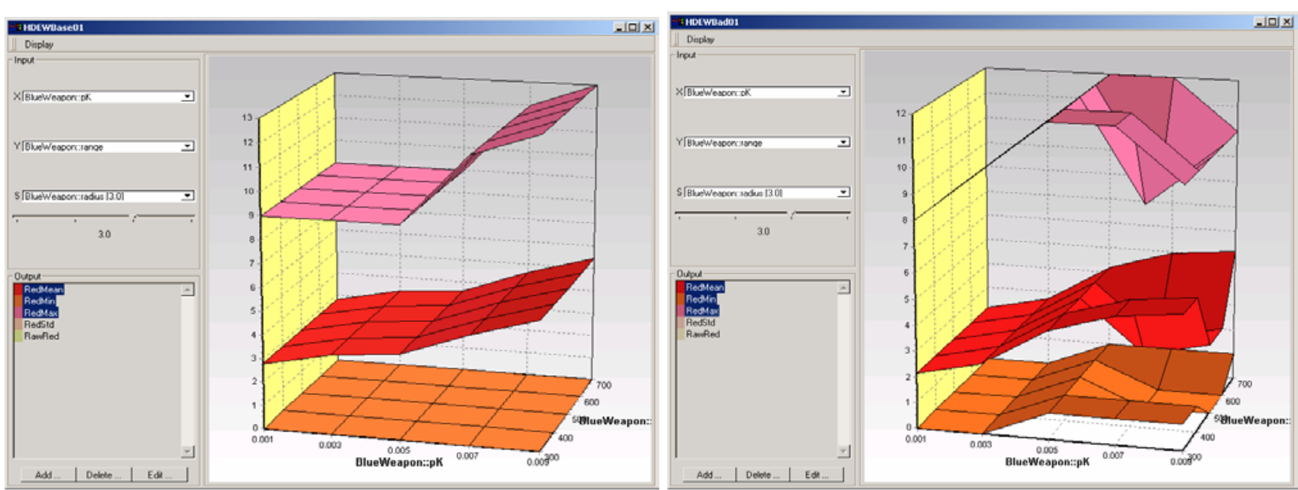

Figure 9: Competent vs Incompetent Case – Variable Weapon Radius.

Figure 10 displays diagrams of this potential phenomenon. In the first diagram, weapon range and radius are small enough that overlap does not exist, but the blue and red agents are not within firing range of each other. Therefore the fact that one blue grunt is incompetent does not impact the situation. In the last diagram, weapon range and radius are large enough that overlap exists between the competent grunts to compensate for the incompetent grunt's low weapon capability. In the middle diagram, overlap is nonexistent and the incompetent grunt impacts the outcome since the gap between the competent grunts is larger than their weapons capability.

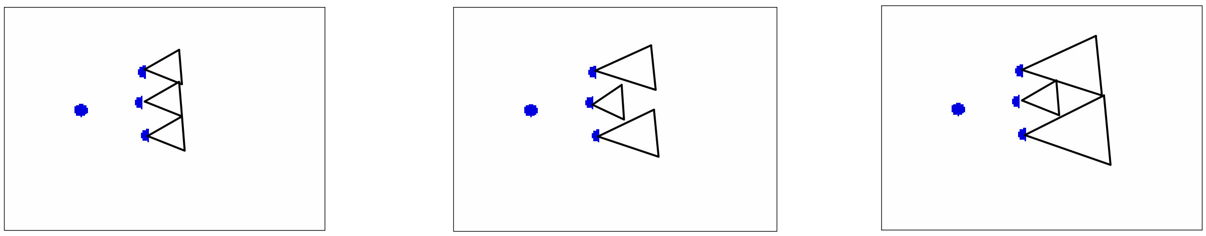

Figure 10: Weapon Fields of Fire Diagram for Competent and Incompetent Grunts.

Figure 11 depicts the third excursion in which the level of one blue grunt's competence is varied to an extreme, from incompetent to extremely incompetent. The figure depicts the fact that the model showed differences in incompetence had little effect. But interestingly, there was a slight negative effect when the incompetent grunt's weapon range was approximately equal to the distance between the incompetent grunt and the competent grunts on its flanks. This appears to be consistent with the results obtained from earlier runs (the fields of fire data) noted in Figure 9.

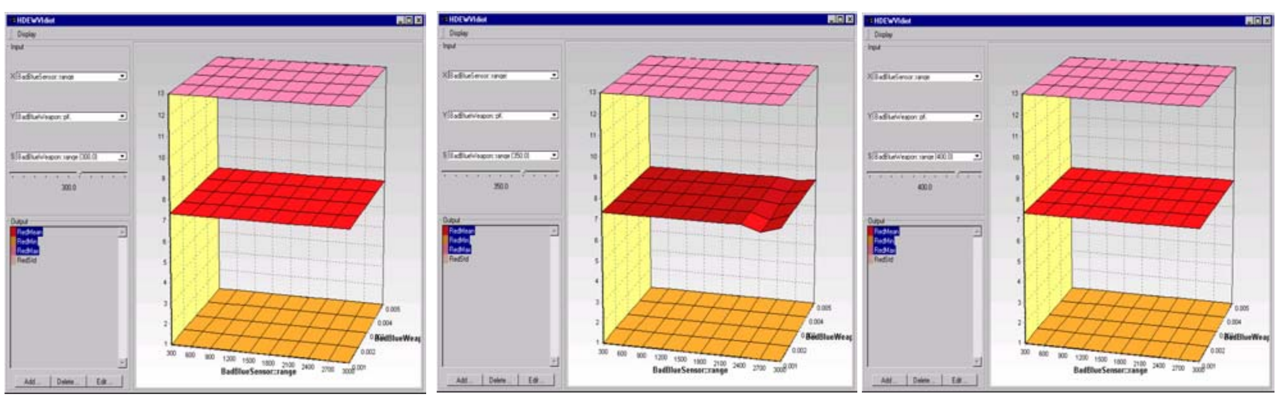

Figure 11: Extremely Incompetent Case – Variable Weapon Range.

5.0 SUMMARY AND FUTURE RESEARCH

In summary, our work is illustrative in nature, but questions regarding C2 in homeland defense scenarios are critically germane at this time. The use of distillations and Data Farming within the philosophy of modeling described in the NATO Code of Best Practice for C2 Assessment may be one way of gaining a better understanding of the answers to these questions. The research described in this paper is a beginning look at two different meanings of an enemy within the system, but plans are for future research along three distinct threads as researchers from the US and Sweden continue to collaborate.

One thread is to flesh out the research started with the given scenarios. Additional ideas include modeling the enemy within the population scenario in Socrates and the enemy within the force scenario in ISAAC, varying the number of both active and distracting red agents, varying the position and number of blue agents, and varying the weapon radius at the same time introducing the possibility of fratricide. Of course, sorting through the resulting "mountain" of data will be formidable, but tools being developed within Project Albert should be useful in this regard. A second thread is to take situations where the research engenders a "flash" of insight within personnel with military and/or homeland defense experience and iteratively produce more data in the areas of interest or potential insight. Workshops within Project Albert have shown that the process of attacking questions with distillations within multi-disciplinary groups often produces emerging ideas and initially counterintuitive results that can be pursued fruitfully and rapidly with distillations and Data Farming. A third thread is to create new scenarios that will allow us to look at the enemy within at different levels of command and control. This research would include plans to examine an enemy who, because of some triggering event, suddenly goes from dormant to "hot" in a given situation. New models, such as MANA and Pythagoras, being added to the suite of models available within Project Albert for Data Farming on high performance computing platforms as well as planned additional feature in Socrates should allow for this examination in the near future.

6.0 REFERENCES

"NATO Code of Best Practice for Command and Control Assessment", Revised Edition 2002 (draft).

Moffat, James, G.L. Mathieson, and D. Shirley, "A Guide to Best Practice in C2 Assessment", Defence Evaluation and Research Agency, UK, August 1999.

Horne, Gary and Mary Leonardi, editors, "Maneuver Warfare Science 2001", Marine Corps Combat Development Command, Quantico, VA, USA.

Hoffman, Frank and Gary Horne, editors, "Maneuver Warfare Science 1998", Marine Corps Combat Development Command, Quantico, VA, USA.

www.militaryscience.org/distillation

www.projectalbert.org

AUTHOR BIOGRAPHIES

Dr. Gary E. Horne is a Principal Scientist with the MITRE Corporation, and the Executive Director of Project Albert working on-site at the US Marine Corps Combat Development Command. His research specialties are developing the Data Farming methodology and applying complex adaptive systems theory to military evolutions, especially in the area of distillations. He recently chaired the Project Albert International Working Session on Homeland Defense.

Dr. Henrik Friman, is a researcher and Project Manager at the Swedish National Defence College, Department of Operational Studies, Stockholm, Sweden. The Department of War Science specializes in command and control research of military science. His professional background is in strategic management, time research, futurology, and command and control systems. Today he works with a project named *Command Concepts*, with responsibility to study Higher Commanders intentions and responses in a context of decision-making.

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C2 Algorithms and Joint Modelling in the COMAND Model

Ian M Campbell
Dstl Analysis
Dstl Farnborough
Hampshire GU14 0LX
UNITED KINGDOM
00 44 (0) 1252 455708
imcampbell@dstl.gov.uk

ABSTRACT

In 1996 the UK MoD highlighted the lack of analytical methods to assess issues relating to the balance of investment in ICS (Information and Communications Systems) and ISTAR (Intelligence Surveillance Target Acquisition and Reconnaissance) systems. A method using two high-level combat models (CLARION, a land model, and COMAND, a maritime and air model) has been developed to assess the impact of these systems on campaign outcome. This paper presents a discussion of some of the key command, control, communications and intelligence (C3I) functionality in one of these models, COMAND, and describes how it links with CLARION to create a joint modelling environment.

Key Words*: Simulation, Research, C3I, Joint, Validation.*

1.0 BACKGROUND

In July 1996, the UK Ministry of Defence (MoD) highlighted the lack of analytical methods to assess issues relating to the balance of investment in ICS (Information and Communications Systems) and ISTAR (Intelligence Surveillance Target Acquisition and Reconnaissance) systems. CDA (Centre for Defence Analysis), now Dstl (Defence Science and Technology Laboratory) Analysis, were asked to develop a methodology to address this. The use of campaign models to assess the achievement of campaign aims and hence advise MoD on balance of investment issues concerning weapons and platforms has been carried out for many years. The challenge was to develop a methodology that would allow ICS and ISTAR systems within the joint battlespace to be judged using these same high level measures of effectiveness.

A methodology was developed utilising the strengths of the then recently developed land/air combat model CLARION (Combined Land/Air Representation of Integrated OperatioNs). In order to consider COMAND in context, it is useful to contrast it with CLARION. CLARION provided a representation of command and control that was well in advance of previously available theatre-level models and had been designed particularly with a view to modelling manoeuvre warfare. However, in order to develop a method that would be able to examine systems across the joint domain, a campaign model that represented the maritime domain and provided a more detailed representation of the air domain was required. Therefore, Dstl Analysis have developed a new model called COMAND (C^3 Orientated Model of Air and Naval Domains) to meet this demand.

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The essential features of COMAND, then, are its C3I functionality and its ability to model the contribution of the maritime and air components to the joint campaign. This paper concentrates on the COMAND model, the key aspects of its C^3 (Command, Control and Communications) and ISTAR functionality and its use together with CLARION to provide a joint modelling environment; it does not, however, discuss the complete methodology for assessing ICS and ISTAR.

2.0 CLARION AND COMAND OVERVIEW

CLARION is a two-sided, time-stepped theatre-level representation of land/air combat. CLARION is capable of being run in both a deterministic and stochastic mode; the stochastic mode is a recent development and introduces random elements into direct fire, sensing and some decision thresholds. CLARION represents the combat and surveillance capability of direct fire, artillery and reconnaissance units, their headquarters, attack helicopters and aircraft. Although CLARION may be used to model a fuller air campaign including defensive and offensive counter air and air interdiction, functionality is most comprehensive on the representation of the land battle.

COMAND is a three-sided[1], stochastic[2], event-driven theatre-level representation of maritime and air contributions to a joint campaign. COMAND has a simple representation of the land battle that allows the representation of joint operations. COMAND's third side allows the representation of neutral aircraft and ships. COMAND represents ships (including aircraft carriers), submarines, aircraft, helicopters, satellites, airbases, ports, strategic targets, land-based missile sites, radar sites and the land battle. It represents the weapons and sensors of these entities and the interactions between entities where appropriate.

Both models have a 'high level' representation, meaning that the scope is broad and that where possible simple algorithms are derived from the result of more detailed lower level modelling.

Both models are PC-based and capable of running within a Microsoft NT Windows environment. Both have been designed with the intention of providing the analyst with an easy-to-use tool capable of giving results in time scales and costs acceptable to customers[3].

3.0 THE COMMAND HIERARCHY AND COMMUNICATIONS

COMAND has been developed with a flexible command hierarchy that allows it to model any command structure or doctrine. It has a Joint Force Commander (JFC) who is in charge of the whole campaign with subordinate domain component commanders.

The maritime hierarchy devolves below the Maritime Component Commander (MCC) to task group commanders who may be in charge of anything from a carrier battle-group to a single submarine.

Most of the air C2 is handled within the Combined Air Operations Centre (CAOC), at a relatively high level. This is represented in COMAND by a range of commanders each of whom takes on the role of one of the cells within the CAOC, for example there is a Defensive Counter Air (DCA) commander, a Suppression of Enemy Air Defences (SEAD) commander, etc.

[1] NATO Code of Best Practice Section 8-B-4 [1].

[2] NATO Code of Best Practice Section 8-B-3 [1].

[3] NATO Code of Best Practice Section 8-B-7 [1].

Land-based assets are handled in a similar way to maritime assets; a commander may be in charge of a group of systems. For example there may be one commander in charge of a side's air defence SAM sites, another in charge of its early warning radars, etc.

Although COMAND is not a communications model, it does represent the flow of key information types. These are listed below:

a) Orders and status reports. These flow down and up, respectively, the command hierarchy.

b) Support requests. Each commander can have a number of other commanders from whom he may request support. This may not necessarily follow the command hierarchy. For example, if the commander of the bombing campaign feels that a particular target may be too dangerous to send manned aircraft against he may directly ask a submarine to fire a cruise missile.

c) Intelligence. The flow of intelligence takes the form of all-informed networks. Whenever intelligence enters a network it is passed to everybody else on that network, although communications delays may mean that not every commander receives the information at the same time.

4.0 MISSIONS AND COMMAND AND CONTROL

Missions are the building blocks from which scenarios are created. They are used equally in all domains and are a task that a commander may be assigned to carry out. Missions fall into the following broad categories:

a) Attack;

b) Escort;

c) Patrol.

The mission-based structure is the key to all of COMAND's representation of command and control[4]. Using this mission-based structure it is possible to represent the 'deliberate' planning of senior commanders at the higher levels of the command hierarchy. This is the type of planning where a commander has enough time to consider the situation in detail and arrive at a course of action, which will look out over a number of days. This course of action takes the form of a plan and contains a series of missions, which is passed down the command hierarchy.

The mission-based structure also allows the representation of bottom-up 'rapid' planning, where field commanders must make quick, time-pressured, decisions about their immediate environment and the threat. Rapid planning allows a commander to elect not to attack an enemy target if it is too strong and instead request support from another commander. At the moment, rapid planning is only represented in the maritime domain in COMAND.

5.0 AIR C2

As previously mentioned most of the air C2 occurs at the CAOC. Here the Air Component Commander (ACC) monitors the status of each domain and assesses the allocation of aircraft to roles. For example, if the maritime campaign is progressing well, but the land battle is not, he may decide to switch effort from maritime attack roles to close air support (CAS).

[4] NATO Code of Best Practice Section 8-B-1 [1].

The status of each domain is measured using Campaign State Vectors (CSVs). These are specific to each domain, but typically take the form of the ratio of the enemy's capability to friendly capability. For example, the maritime CSV is the ratio of each side's anti-surface warfare (ASuW) and anti-submarine warfare (ASW) capability.

During the process of planning each day's sorties the ACC conducts a fast, deterministic, run-through of each mission in order to assess its support requirements. During this process, if losses for a sortie exceed a user-specified level even after adding as many support aircraft as he can then that sortie is removed from the Air Tasking Order (ATO) and the released effort spread amongst the other missions, if possible. At this stage the ACC may then request support from other commanders holding land-attack cruise missiles.

6.0 RAPID PLANNING

Each commander maintains a track table, which endows him with a degree of situational awareness. This track table is built up using the group's own organic sensors (radars and sonars onboard ships, the dipping sonars of helicopter screens, etc.) and also via any intelligence networks the commander has access to. Through the intelligence networks a commander may have access to the sensors of maritime patrol aircraft, other task groups, airborne early warning (AEW) aircraft and satellites.

Each track contains information such as platform type, bearing, speed, etc. and may be built up from a number of different sensors, each one providing a different piece of information. Perfect track fusion is assumed in compiling the information. Each track is time-stamped and if it is not updated after a certain length of time then it is discarded.

In COMAND, the key to rapid planning is the commander's threat assessment, which is carried out based on the contents of his track table. Delays in receiving information on those tracks may lead to a commander making inappropriate decisions. This is one of the key impacts of communications on the model.

A commander may be in one of two postures, either offensive or defensive, which are defined according to the particular mission he is carrying out. For example, a fast patrol boat (FPB) may be set-up to have an offensive posture. This limits the commander's perception of what a threat may be to only those tracks that he believes may shortly come within weapon range of him. This allows him to ignore tracks and carry on with his assigned mission unless he believes they will be able to interfere. However, a carrier battlegroup may have a defensive posture. This allows the group to dominate a large area considering everything that moves to be a threat and to be dealt with appropriately.

Once a track becomes a threat, an assessment is carried out in order for the commander to arrive at a course of action. The threat assessment process involves taking the perceived capability of the threat and comparing it with his own. If the assessment is unfavourable then the commander may seek to evade the threat and request support from other commanders, as defined by the user, to prosecute the contact; if it is favourable then the commander may elect to attack the threat himself.

7.0 JOINT MODELLING

Dstl Analysis does not currently have a single combat model capable of allowing a comprehensive examination of joint operations. Therefore, it has been a requirement from the outset of the development of

COMAND that it should have the capability to interface with CLARION, thus allowing capabilities and systems across the joint domain to be assessed in a robust, efficient and balanced way[5].

Such an interface may be achieved manually in the current versions of the models by utilising COMAND's simple aggregated representation of the land battle (called SLAM (Simple Land Analysis Model)), based on historical analysis[6] algorithms. These algorithms were empirically derived by examining the key factors that have influenced the outcome of past conflicts. Within COMAND this provides a dynamic representation of the land battle that allows the JFC and the Land Component Commander (LCC) the opportunity to monitor the progress of the land battle and change their campaign plans appropriately. It also enables assets such as aircraft and naval gunfire to influence the land battle.

If the models were to be used together, relevant data such as that shown in Figure 1, below, would need to be passed between them. COMAND would provide the numbers of sorties flown and availability of assets that could influence the land battle. CLARION would then be run to provide key outputs in order to calibrate SLAM within COMAND. This process may need to be carried out iteratively until stability within the models is achieved.

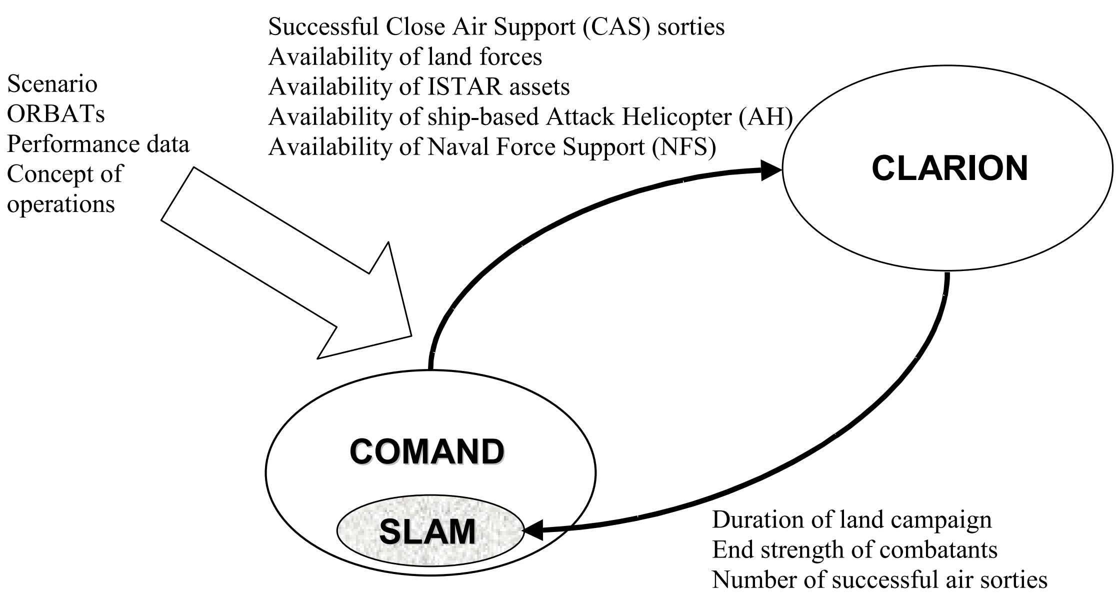

Figure 1: Manual Linkage between COMAND and CLARION for Joint Modelling.

In the future it is hoped that COMAND may be linked to CLARION in 'real time' via High Level Architecture (HLA). This will allow the models to trade key communications between commanders and interactions between domains.

[5] NATO Code of Best Practice Section 8-B-2 [1].

[6] Historical Analysis is the extraction of quantitative information from past conflicts. It is of most value in identifying and quantifying factors that reflect human behaviour and capabilities in battle, since these are difficult to pin down by other means.

8.0 VALIDATION EXERCISES

COMAND has been extensively validated; three strands were used in the validation process, listed below[7]. This section, however, will only give a brief overview of the first.

a) Historical comparison – 1982 Falkland Islands conflict;

b) Comparison against future conflicts using current Dstl campaign models – the Maritime Campaign Model (MCP) and the Theatre Analysis Model for Air-Related Issues (TAMARI);

c) Data review.

The three strands were selected to allow the programme to cover the whole scope of validation. Past conflicts, which enabled the non-technology aspects that can affect a campaign to be investigated. Future conflicts, which the model will be used to represent in practice. Data review, to ensure that data are as up-to-date as possible and in the correct form for input to the model.

The 1982 Falkland Islands conflict was selected because it is one of the few instances of modern naval combat operations. Figure 2 illustrates one of the key measures used in the validation exercise: the number of UK ships destroyed in the conflict over time. The dashed line is the number of ships lost in reality, the solid line is the mean number of ships lost from COMAND and the thin dotted lines are the 95% confidence intervals.

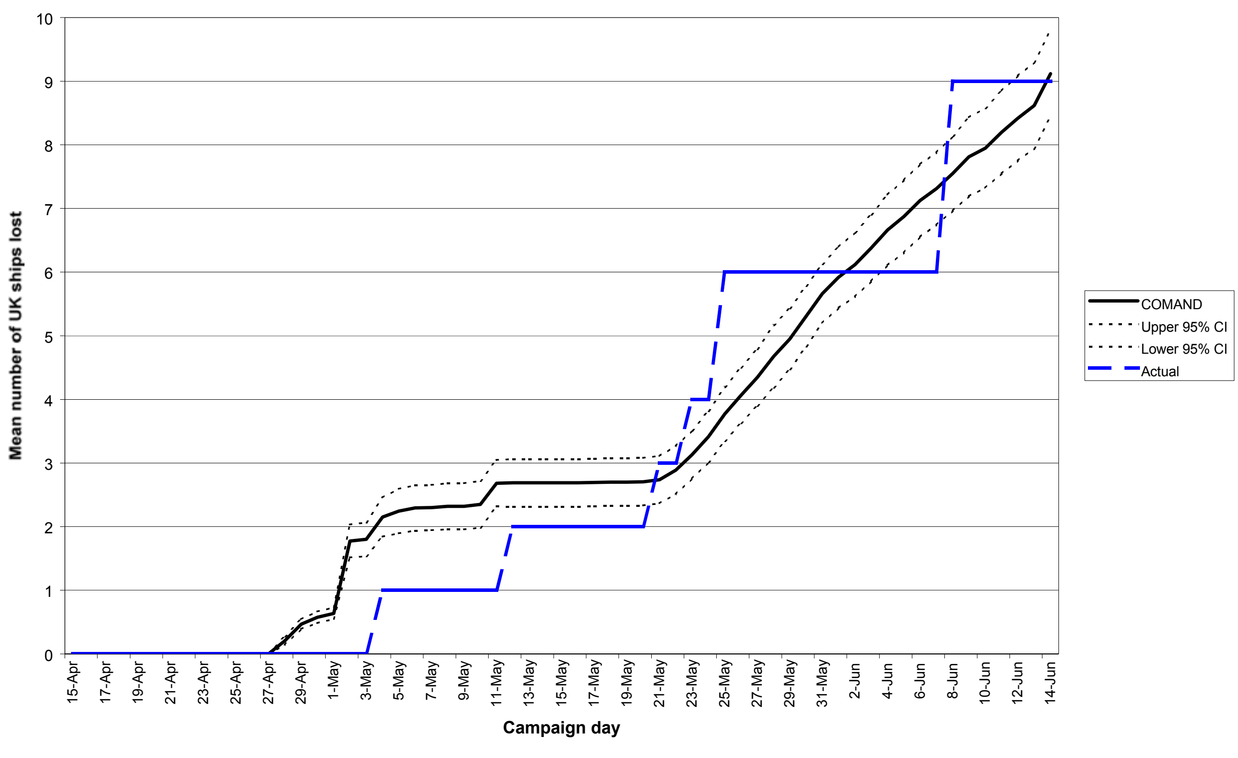

Figure 2: Comparison of UK Ship Losses in COMAND and Reality.

[7] NATO Code of Best Practice Section 8-B-5 [1].

Figure 2 shows that COMAND was able to produce similar results to those from the actual campaign. The only significant data change was to the Argentinean sortie rate, which was degraded to account for the poor weather predominating for much of the campaign. This is why, from 21st May, UK ship losses in COMAND increase smoothly, whereas in the real campaign there are large steps. System performance data were based on analysis of the actual campaign conducted at the time, so if 3 out of 10 bombs that were dropped actually hit, a probability of hit of 0.3 was used in COMAND.

The key part of the curve occurs from 21st May, when the Task Force entered San Carlos water, and UK ship losses begin increasing steadily. This is because the Task Force could be easily detected by the Argentinean sensors based on the Falkland Islands and allowed the Argentineans to generate sorties against those ships. In previous models, this behaviour would have been scripted.

This validation exercise demonstrated that COMAND was capable of representing an expeditionary maritime/air campaign providing significant confidence for study use. In addition, using a historical scenario highlighted areas that were of importance to the battle but not modelled explicitly, such as, in the example above, weather.

9.0 SUMMARY

COMAND allows the analyst to examine the merits of different deployments, force structures and system mixes within a variety of scenarios in the joint domain, especially allowing ICS and ISTAR systems to be assessed using the same traditional high level measures of effectiveness as platforms and weapons.

The C3I functionality within the models provides the opportunity to show the benefits of investing in better ICS and ISTAR systems. Decision making entities that receive better and more timely information are able to make better-informed decisions. Consequently, entities may then act in a way they believe to be of most advantage, which may mean evading rather than engaging a hostile threat of greater capability. This represents a significant step forward from the attrition-based models previously used.

Although COMAND with its simple land representation can be termed a ‘joint’ model, it does not represent the land battle in sufficient detail to offer a balanced assessment across the joint arena. However, linked manually or via a network, COMAND and CLARION are able to achieve this in a robust and efficient manner.

Following an extensive validation a high degree of confidence exists in COMAND’s capabilities, both as a tool for assessing the impact of ICS and ISTAR on campaign outcome and in its role as a campaign analysis tool.

COMAND is one of a new wave of models that reflects the changing nature of conflict, being driven by command and control and the use of information to drive successful prosecution of a campaign.

10.0 REFERENCES

[1] NATO Code of Best Practice on the Assessment of Command and Control.

[2] Moffat, 2002.

11.0 LIST OF ACRONYMS

ACC	Air Component Commander
AEW	Airborne Early Warning
AH	Attack Helicopter
ASuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
ATO	Air Tasking Order
C2	Command and Control
C3	Command, Control and Communications
C3I	Command, Control, Communications and Intelligence
CAOC	Combined Air Operations Centre
CAS	Close Air Support
CDA	Centre for Defence Analysis
CLARION	Combined Land/Air Representation of Integrated OperatioNs
COMAND	C3 Orientated Model of Air and Naval Domains
CSV	Campaign State Vector
DCA	Defensive Counter Air
DERA	Defence Evaluation and Research Agency
Dstl	Defence Science and Technology Laboratory
FPB	Fast Patrol Boat
HLA	High Level Architecture
ICS	Information Communication Services
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
JFC	Joint Force Commander
LCC	Land Component Commander
MCC	Maritime Component Commander
MoD	Ministry of Defence
NFS	Naval Fire Support
RoE	Rules of Engagement
SAM	Surface to Air Missile
SEAD	Suppression of Enemy Air Defences
SLAM	Simple Land Analysis Model

AUTHOR BIOGRAPHY

Ian Campbell is an analyst with Dstl. He is experienced in high-level combat modelling and has worked on a range of C3I-related studies. He has an honours degree in Aeromechanical Systems Engineering from Cranfield University.

The DIAMOND Model of Peace Support Operations

Peter W. Bailey
Dstl Analysis
High Level Studies
Ively Road
Farnborough, Hampshire GU14 OLX
UNITED KINGDOM
+44 (0)1252 455304
pwbailey@dstl.gov.uk

ABSTRACT

DIAMOND (DIplomatic And Military Operations in a Non-warfighting Domain) is a high-level stochastic simulation developed at Dstl Analysis as a key centrepiece within the Peace Support Operations (PSO) 'modelling jigsaw'. It is designed to examine the utility of military force elements and equipments, the effectiveness of future force structures, and possible outcomes of different operational strategies within PSO. It represents the differing parties in a PSO, which may include military organisations, non-combatants, Non-Governmental Organisations (NGOs) and civilians, together with their relationships.

Key Words*: Simulation, Peace Support Operations, Multi-sided.*

1.0 INTRODUCTION

1.1 Dstl Analysis

Dstl Analysis is the operational research (OR) arm of the Defence Science and Technology Laboratories (Dstl). Most Dstl Analysis study programmes support UK Ministry of Defence (MoD) planning processes on policy, procurement and operations. Conventional combat has in the past been the core study area for Dstl Analysis. To support this, a wide range of OR tools and techniques have been developed to support Dstl Analysis' study programmes. However, since the end of the Cold War, greater emphasis has been placed on understanding operations that fall outside of conventional combat. In recent years, the ever-increasing commitment of the UK's armed forces to Peace Support Operations (PSO) has exposed a shortfall in high level modelling tools suitable for analysis of non-warfighting military tasks. As a consequence of this shortfall Dstl Analysis is in the process of restructuring part of its tool-set to meet PSO OR requirements. DIAMOND (Diplomatic and Military Operations in a Non-warfighting Domain) is part of that programme.

1.2 The PSO Modelling Jigsaw

Modelling PSO is still a new and evolving area for the OR community. Rather understandably for such a young discipline there are many pieces to the 'jigsaw' but not yet the understanding of how they all fit together to provide the complete picture. In fact it could be argued that as a community we are still uncertain of which pieces we need to complete the jigsaw, let alone how they fit together. Figure 1 represents some aspects of this jigsaw and some of the pieces we have access to.

Paper presented at the RTO SAS Symposium on "Analysis of the Military Effectiveness of Future C2 Concepts and Systems", held at NC3A, The Hague, The Netherlands, 23-25 April 2002, and published in RTO-MP-117.

GAMING Pol-Mil gaming Computer assisted wargaming Tabletop wargaming	**SIMPLE ANALYSIS** Troops to task rules Concurrency modelling Military & expert judgement	**COMBAT MODELLING** Campaign level models Operational level models Tactical level models Logistics models C3I models
EXERCISES Computer assisted training Field exercises	**PSO HIGH LEVEL SIMULATION** **?**	**THEORY** Academic Institutions Lessons learnt Policy Doctrine
OPERATIONS UN operations NATO operations Africa Indonesia Balkans	**DATA** Geographical Demographic Environmental Equipment effectiveness Historical	**HUMAN BEHAVIOUR** Psychological modelling Sociological modelling Game theory Hyper & Meta games Power analysis

Figure 1: The PSO Modelling Jigsaw.

In answering any OR question on PSO it is important to examine the tools and techniques available to us and decide which of the pieces are most appropriate to answer that question. Some may be answered from a single source such as a database whereas others will require a combination of tools and techniques. Very complex questions, such as those concerning policy and force structures, require a wide selection of tools and sources and quickly become either too expensive to do or too complex to examine rapidly. One proven way to offset these disadvantages is to deploy simulation models that focus the data, techniques and understanding from other sources and provide an analytical environment in which to study complex questions. Figure 1 suggests that there is currently no tool available which fits the requirement for the high level simulation of PSO. DIAMOND, once completed and validated, will fill this requirement and provide a simulation model suitable to draw on the surrounding data, tools and techniques that we already have access to.

1.3 Requirement for DIAMOND

DIAMOND is under construction to address Force Development issues associated with peacekeeping, peace enforcement and humanitarian aid operations. Part of this requirement involves providing a tool to assist in answering the following types of question:

- Which force elements are essential to maintain the military mission?
- What is the utilisation of each force element[1] ?
- Are force elements used in their primary role or do they substitute for high demand elements?
- Are such substitutions efficient?
- How robust is the force mix option in adapting to changing political and military circumstances in theatre?

[1] Force element is defined as a company, battery or individual aircraft or ship.

- What is the ideal force mix to support an operation?
- What is the ideal force structure to support a wide variety of potentially concurrent operations?

One tool to answer these questions is a simulation model. In Figure 1, High Level Simulation (ergo DIAMOND) is shown at the centre of the puzzle. This is not to suggest that DIAMOND is the ‘final piece’ in the PSO jigsaw but to show that DIAMOND links into all the pieces that surround it. For high level force development work this is the logical arrangement of the pieces but for other studies, such as procurement or balance of investment, DIAMOND may sit on the periphery or provide no significant contribution to an OR solution at all.

It is also important to state that the current design for DIAMOND is not intended to provide a ‘single model’ solution for analysing policy and force development PSO issues. Although many aspects of the other tools and techniques can be incorporated directly into DIAMOND (e.g. data and doctrine) the model will still require indirect support from other areas. For example, DIAMOND may rely on other models or wargaming to develop an initial concept of operations and scope the political constraints for any given scenario.

For any study there will inevitably still be pieces of the jigsaw missing but as our understanding of PSO deepens those pieces will be discovered and introduced into the picture. As DIAMOND is an evolutionary development, the model will be continually improved to take into account our increased understanding of the domain and the model itself. DIAMOND has already highlighted some areas where we have either very little or no suitable data with which to examine particular aspects of PSO operations (e.g. refugee movements) and thus its development can be used to focus other work on collecting and assimilating information for study use.

1.4 Development Programme

The DIAMOND project began in August 1998 with a series of workshops to scope the requirement and focus the development on the core aspects of peacekeeping, peace enforcement and humanitarian aid. This resulted in the production of an outline requirement document establishing the aims and boundaries of the project. Following this a detailed requirement was written later that year as the foundation for all future work. A further eight months development effort followed and resulted in the production of the functional specification which outlined how the requirements would be implemented to produce the DIAMOND model. In September 1999 further workshops were convened to complete the design and begin the process of coding the model.

A working version of the model was delivered at the end of August 2000 with the model to be validated, commissioned and in use by April 2002. As the project is an evolutionary development it likely that further design and coding will occur after this date to build on lessons learnt and to incorporate research generated from the delivery of the first version of the model.

The validation exercise has examined a number of historical operations. These operations were chosen to meet specific aspects of the validation process as detailed in Figure 2. The intention of the validation exercise was to confirm that DIAMOND could be used to generate a feasible representation of the historical operations, it was not intended to calibrate the model to them. The reason for this is that the historical cases only represent one possible outcome and this outcome may not be the norm for operations of that type. The validation has concentrated on those areas of the model for which we have supporting data. There is also a parallel stream of work investigating other data sources, principally in those areas for which we have little or no prior experience of modelling (e.g. the humanitarian aspects such as food and water requirements and the effect of diseases). There will, of course, remain some data items that we cannot, currently, obtain supporting evidence for. It is believed, however, that the existence of DIAMOND will provide a focus (and rationale) for future data collection efforts.

Scenario	Validation Aspects
Bosnia IFOR, 1995 (Peace Keeping)	Test the boundaries of the model in terms of the size of scenario which can feasibly be represented and, more importantly, analysed
Mozambique, 2000 (Humanitarian Aid)	Test the humanitarian and engineering aspects
Sierra Leone, 2000 (Peace Enforcement / Evacuation)	Test the conflict and party interaction processes

Figure 2: Validation Scenarios.

The model was developed using the Rational Rose object-oriented modelling tool, Visual C++, Windows NT4, Microsoft Foundation Classes and DROMAS version 2.63.

2.0 TECHNICAL SPECIFICATION

2.1 Overview

DIAMOND is a fast running, high level, stochastic, object-oriented simulation of peacekeeping, peace enforcement and humanitarian aid operations (PSO). The major aspects of the technical design are summarised below.

A simple node and arc network provides a graphical representation of the region and environment allowing the model to represent key areas of interest, areas of sea or lake and the airspace above. Key facilities, such as airports and civilian shelter can be represented.

The model allows for the representation of key actors and contributors to PSO by use of Entities. These represent the capabilities and behaviours of military units, civilians, non-military organisations and the leaders or commanders for each. Entities interact with each other and the environment and exchange or consume key commodities such as food, fuel and ammunition.

The model incorporates a mechanism to organise entities into common ‘parties’ that represent specific organisations or common groups within a scenario. These parties have an appropriate command structure and communications network to facilitate the allocation of missions and flow of intelligence throughout the party. Parties have relationships with one another which define their interactions.

The model includes a mechanism to represent each party’s concept of operations by nesting objectives in a series of plans and for those objectives to consist of a series of missions that entities can prosecute during a campaign. Commanders within a party allocate resources to achieve their objectives in line with the sequence of plans and the simulation completes when a set number of parties achieve their end state conditions or when a predetermined period of time has elapsed.

During a model run entities gain information on their environment and other entities through sensing, interactions and communication. This information is organised into a local picture which allows those entities to make informed decisions on how they should prosecute their missions and activities delegated to them by their superior commanders.

Finally, DIAMOND includes a mechanism (referred to as negotiation) to obtain access to an area denied to one party by another and to allow multi-party co-operation to achieve aims and objectives without having to rely entirely on their own resources.

2.2 Environment & Facilities

A node and arc network provides the physical environment in DIAMOND. Nodes represent areas of operational interest, population centres and the locations of key infrastructure and terrain features. Arcs represent the routes between these nodes. An example Node – Arc network for DIAMOND is shown in Figure 3.

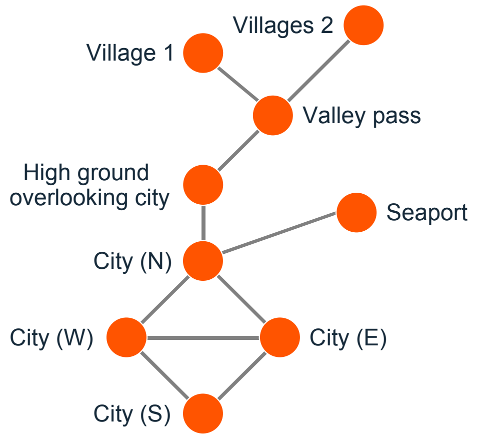

Figure 3: Example Node - Arc Network.

Nodes can, depending upon the nature of the scenario, represent whole cities such as London or individual districts or regions within a city such as Chelsea, Lambeth, Westminster or East and West London. They can be used to represent individual villages but it is proposed that a more appropriate aggregation level would be collections of villages. Nodes are also used to mark areas of deep water, points along an air corridor, strategic junctions and key terrain features.

Arcs represent the routes between the nodes and each one has several channels which can include ground routes (which aggregates the road, rail and cross country links), air corridors, inland waterways (canal, river, lake crossing aggregated), littoral waterways and deep waterways. The anticipated length of each arc is around 10 to 30km, although this can be much shorter where areas of interest are close to one another (e.g. the districts of a city).

The type of channel (and its capacity) determines which entities can move down that arc. For example, large ships cannot transit an arc connecting two water nodes with only an inland waterway channel (e.g. a canal), as they are prohibited from using any channel that is not a deep-sea waterway.

When defining the node/arc network (Net), the user must take care to ensure that the Net is established with a level of granularity appropriate to the entity size, i.e. division-sized entities on a Net where individual nodes represent single villages and settlements would be inappropriate. It is proposed that for an environment represented as cities, towns or districts with arcs between 10 to 30km then the appropriate entity size for military units is battlegroup, air package[2] and individual ship.

Nodes and Arcs both have a terrain type (called culture) which influences a variety of calculations such as the effectiveness of sensors, the rate of attrition between two units engaged in combat and movement rate. These culture types are: Urban, Suburban, Open Flat, Open Rolling, Open Mountainous, Scrub, Lightly wooded, Densely wooded, Mountainous and Open Water.

[2] Battlegroup: approximately 3 to 4 companies, Air package: approximately 1 to 4 aircraft.

Weather is also modelled and encapsulates factors with local, temporary effect. Weather on an arc defaults to the weather of the nearest node; ergo the midpoint of arcs is where weather types can change between different areas of interest. The weather condition at all points on the net is known by all entities. Advance forecasting of weather is not modelled in the first release of DIAMOND but may be introduced in later developments. Day and night is also not represented but, again, may be introduced in subsequent developments.

At each node it is possible for the user to define facilities, which are key attributes of that area that any entity can interact with. The facilities modelled in DIAMOND are: Shelter, Hospitals, Airports, Seaports, Targets. Each facility has the following generic attributes:

Damage points: The damage points for a facility indicate how hard it is to eliminate. Damage points are represented by two fields: the maximum damage points a facility can sustain before it is eliminated (or at least ceases being targetable by weapon systems) and its current damage points. Note: facilities may start a scenario already part damaged.

Capacity or Output: Most facilities produce an output or service of one type or another. For example, shelter has the capacity to house people; hospitals have the capacity to treat a number of patients per day. The capacity or output is different for each facility but the concept of capacity is generic across all facilities. The capacity can be degraded with damage. Therefore there are 2 fields: maximum capacity and current capacity. Both of these are dynamically calculated at the start and/or throughout a run.

Damage point to Capacity point conversion factors: As damage points inflicted affect the capacity of a facility the relationship between damage sustained and capacity is governed by the Damage point to Capacity point conversion factor.

Self-Repair capability and Self-Repair Threshold: Although engineering and construction entities in the simulation perform repairs, all facilities are likely to have an intrinsic self-repair capability based on the manpower and/or specialist equipment at the site. For example, civilians can repair light damage to their homes by boarding up windows, replacing missing tiles or through other makeshift repairs. Plumbers, builders and other specialists within the community could repair heavier damage and would not necessarily be represented by a special entity. These effects are represented by the Self-Repair capability, which is the number of damage points that facility may repair itself per day. Only when damage is very heavy and widespread do these local services become ineffective. As such, the self-repair capability of any facility will be limited and may cease to operate if the damage is heavy. This is represented by the Self-Repair Threshold, which is the number of damage points above which the Self-Repair capability is available.

Residual Capacity and Residual Threshold: Not all facilities can be totally destroyed and therefore even when fully damaged they may provide a residual capacity. For example, even if a hospital was destroyed some of the doctors could remain in the area and operate out of any acceptable premises. Consequently, a residual capacity is another general attribute of facilities. It is the minimum capability a facility can provide even if it has sustained maximum damage.

2.3 Entities & Activities

The entities in the model can be considered to fall broadly into the four categories below:

Intervention Forces: These are the Peacekeeping and Peace Enforcement forces with entities representing land, air, maritime and special forces units operating under a UN or other international mandate. Supplementary police forces to assist a failed state are also covered under this category.

Factions: The military and paramilitary forces of belligerent or warring factions who are not part of the peacekeeping or peace enforcement forces. The host nation's forces are also covered under the heading of factions. The entities include land, air, maritime and special forces units.

Non-military organisations (NMOs): NMOs include monitors and observers, commercial companies, governmental and international humanitarian agencies and non-governmental organisations.

Civilians: Civilians, including neutral civilians and those associated with individual factions, internally displaced persons, refugees and evacuees.

Each of these categories of actor can be represented in the model through use of an entity template. There are 5 types of template available. 3 are for different levels of commander, 1 for civilians and the other is a generic template used to describe all land, sea, air and NMO entities. In summary the templates are: Joint Theatre Commander, Component Commander, Intermediate Commander, Civilian Entity and Generic Entity.

Although 3 types of commander are specified it is implicit for both civilian and generic entities that they can command themselves if they have no direction from a superior. They have their own local picture and are capable of making decisions for their own survival and to achieve their missions. The higher level commanders allow for additional considerations, such as deciding which stage of a campaign plan should be followed, allocating resources to missions and directing a number of subordinate entities to work together to achieve a common goal.

Each template allows the user to define a number of key descriptors for that actor in the simulation: movement rate, size, sensor package, combat ability, transport capability, civilian/military identifier, commodity consumption rates, communications networks, engineering capability and the missions the entity is eligible to perform.

The proposed aggregation levels for land, air and maritime units in DIAMOND are battlegroup, package and single ship respectively. Civilian populations can vary between several hundred and several million and NMOs are likely to be small units of variable size and attributes.

As commanders represent headquarters, local government, individuals and in some cases the intangible collective actions of a set of common entities (e.g. refugees) their size is entirely user defined.

To allow the model to calculate 'entities to tasks' all entities, regardless of their size, are standardised in terms of 'components'. For military land units a component represents a deployable company or squadron and for maritime and air forces a component represents a single ship, boat or airframe. This choice was made to allow components for land units in DIAMOND to map directly from lower level combat models and for combat outcomes from those models to populate lookup tables in DIAMOND.

Although no detailed work has been done on what is an appropriate component level for NMOs it is proposed that a size of component comparable to their military counterparts be used in the first instance. Although this will mean some NMO entities will represent fractions of a component (e.g. a single land rover and two aid workers equals about 0.02 of a component), the entities to task rules can be written with this in mind and allow DIAMOND to substitute military and non-military entities between tasks (e.g. bridge repairs, food distribution).

2.4 Sensing & Communication

In DIAMOND, sensing & communication cover the processes by which entities directly acquire information about other entities, events and the environment. Sensing covers 3 processes: direct observation, use of a sensor such as radar and experience of events such as interactions with other entities and the environment. The representation of sensors has been kept as simple as possible for the first release of DIAMOND. Rather than have explicit representation of known sensors such as radar, optics etc., the user is able to give names to generic sensor packages. A sensor package represents the collective sensor performance of that entity. For example, a British battlegroup can have numerous visual, IR and radar sensors plus the eyes and ears of over 500 soldiers. In DIAMOND this can be represented as a single sensor package. A unique name and the component types it is capable of detecting define each sensor package.

For the first release of DIAMOND 'cookie cutter' templates represent the range of sensors. The surrounding culture type of any target entity, the size of that entity and the local weather conditions modifies these ranges. Any item that falls within this adjusted maximum range of the sensor package will be detected and all entities that fall outside will evade detection. Different ranges within the cookie cutter determine the resolution (i.e. the detail) that the sensor information can provide (Figure 4).

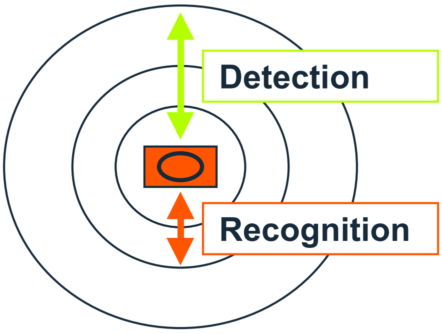

Figure 4: Representation of Sensors.

All information received by an entity (whether that be through sensing or communication) is assimilated into its local picture. The representation of local picture (and perceptions based upon it) is an important aspect of DIAMOND, as all entities decide what to do in the simulation on the basis of the information available to them. If this information is incomplete or out of date the entity's actions may be different, compared to their actions based on complete and current information. The local picture in DIAMOND is defined as the aggregation of all information made available to that entity with perfect and efficient data fusion. Perception is the translation from what that perfect picture looks like into what the entity 'believes' it knows. For the first release of DIAMOND local picture maps 1:1 onto perception. In subsequent developments the perception function may be enhanced to allow for misinterpretation, double plotting and extrapolation of information in the local picture.

Each piece of information recorded in the local picture consists of four items. They are: Unique identifier, Resolution, Credibility, Timestamp.

Unique Identifier: The unique identifier records the individual identity of every object in the simulation. This information is required by the model to ensure the same object is not plotted twice in the local picture. As the local picture is defined as the most efficient fusion of data the model will always plot the most useful combination of information relating to that unique object. This effect is not true for the perception picture where errors may occur (i.e. the object is plotted twice, it is plotted in the wrong place, it is mislabelled, it is mis-identified, or it is ignored). However, as previously stated, perception is not modelled to this level of detail for the first version of DIAMOND.

Resolution: The resolution class determines the detail of the information available about that entity. There are 5 levels of resolution, ranging from the least detailed, detection, through to the most detailed, analysis. In DIAMOND as soon as a level of detail is acquired about another object it is time stamped against the unique ID of that entity and the specific information gathered at that level is recorded to a temporary store. That information can then be recalled whenever an entity consults their local picture about that specific piece of information.

Credibility: The credibility of the information (which is dependant upon the source of the information, previous credibility assigned to that information and the entity receiving the information) is also recorded. There are 5 levels of credibility in the model, ranging from certain through to incredible. Credibility influences whether entities use or discard that information when they make decisions based upon the information in their local picture. In the first version of DIAMOND the credibility may be detached from the other three data items (resolution class, timestamp and unique ID) to replace a lower credibility on a more accurate or up to date version of the same object (i.e. better resolution or timestamp).

Timestamp: It is important to timestamp when information is gathered because it is not instantaneously transmitted around a party's communications network. Hence this identifier ensures that only the most up-to-date information is recorded (not necessarily the most recently received). The model does not currently degrade information due to its age although this is a potential future enhancement.

Communications can be of four types:

Regular: Regular (or event triggered) communication between superiors and subordinates within a single party's communication network.

Direct: Communication between a commander and a subordinate entity from a different party who has been instructed to co-operate by its superior commander. This is a temporary (dynamic) link that will end when the mission they are co-operating on is complete.

Broadcast: A global broadcast that reaches all entities with a receive capability for that broadcast type.

Negotiation: Negotiation between two entities from different parties who are in the same 'peer group' (in the current implementation of DIAMOND only the highest-level commanders can negotiate). Examples include requests for escort, requests for supplies and requests for access. Negotiation is assumed to be supported by appropriate communications systems (e.g. radio if negotiating at distance, interpreters if negotiating face to face).

For communications DIAMOND represents a number of communications networks. Some nets (such as military networks) are party-based, while others (such as commercial news stations) are 'global'. Messages communicated include orders, status reports, requests for assistance, intelligence, local picture information and media broadcasts.

An entity will always communicate with its superiors and subordinates. The user can also create special nets to allow communications that do not follow the command structure. For example, these might include media, the 'rumour' network and face-to-face communication. On occasions this will occur dynamically is when an entity is assigned to operate for a commander (possibly in another party) that is not his direct superior. Under these circumstances the entity will report directly to its hierarchical commander and to the commander who has Operational Command (OPCOM) of that unit.

Broadcasts and directed messages are subject to delay at each level of command. Interoperability problems within a multinational force can be represented by additional delays in transferring information from one net to another when an entity has access to both. In DIAMOND entities from different parties may have 'receive' only links with other parties connected to the communications network to represent the sharing of intelligence.

2.5 Missions & Decision Making

The activities of entities within the environment are governed by 2 criteria. Firstly, the missions (i.e. tasks) represented in the model that entities are eligible to perform and secondly, the decision making processes in each party that determines how and when those missions should be prosecuted.

There are 12 missions in the model. They are: Transport, Intelligence, Move, Engineering, Defend, Reserve, Evacuate, Escort, Presence, Strike, Secure and Deny movement.

The majority of the missions cover general tasks that any entity in the simulation could undertake (Transport, Intelligence, Move, Engineering, Defend and Reserve). The other missions are those that are likely to be specific to either the peacekeeping forces (Evacuate, Escort, Presence and Strike) or to the belligerent factions (Secure and Deny movement). This is not to prevent the missions being interchangeable between the different parties within DIAMOND but to indicate that the design has focused on providing specific tasks associated with the principal actors involved in PSO. Each of the missions is interpreted by the entities that perform them as a series of activities. For example, the transport mission consists of the sequence: Plan, move, commodity exchange (i.e. load), move, commodity exchange (i.e. unload), reserve (i.e. become available for a new task) and communicate (i.e. report to superior commander that the entity is now available for new missions).

The missions themselves are organised into concurrent and sequential packages, referred to as plans. For example, a plan may include a mission to secure an area after which several transport and presence missions may occur concurrently. The entities undertaking the missions within the plan report at regular intervals whether they are succeeding or failing and their superiors may allocate additional resources (if they have them) to move failing missions back towards success. The relationship between plans, missions and activities is shown below in Figure 5.

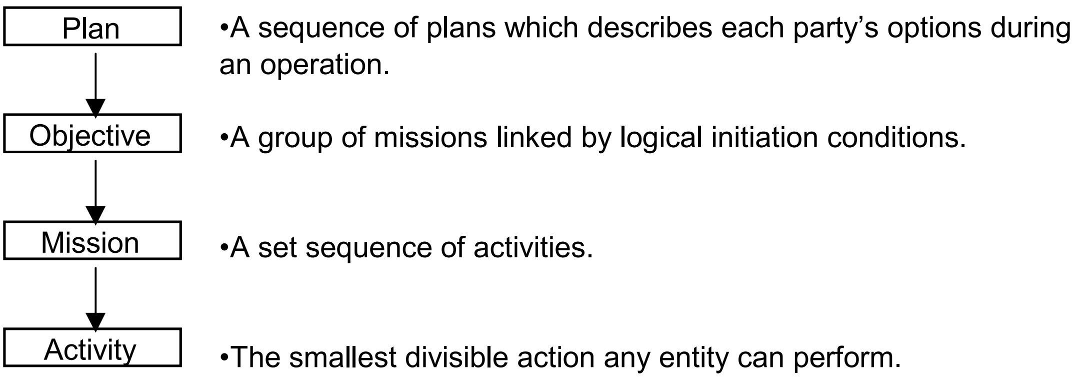

Figure 5: Relationship between Plans, Objectives, Missions and Activities.

Monitoring the overall progress of the plan is the Joint Theatre Commander (JTC) or his NMO equivalent. The JTC’s perceptions include a function called the Campaign State Vector (CSV) and it is the CSV that indicates to the JTC whether the plan is succeeding or failing. Each plan has an associated set of initiation conditions and end conditions, which may be time dependent and/or success dependent. If a plan is failing (or has completed) the JTC will decide which is the next most appropriate plan to follow. This sequence of plans forms the party’s Concept of Operations (Figure 6).

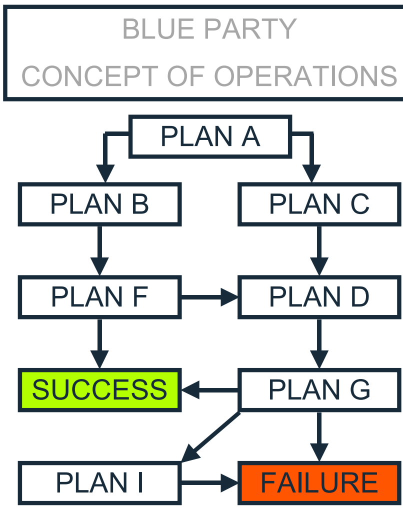

Figure 6: Example of a Party's Concept of Operations.

The 3 types of commander in DIAMOND make decisions associated with the progress of plans or missions. The levels of commander are the Joint Theatre Commander (JTC), the Component Commanders (CC) and the Intermediate Commanders (IC). There is technically a fourth level of commander, the entities themselves (military units, NMO's and civilians). This is shown diagrammatically in Figure 7.

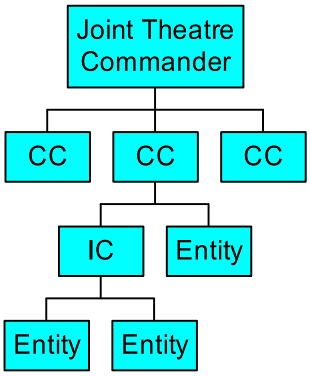

Figure 7: Command and Control Hierarchy.

The JTC controls the progress of the campaign by deciding which plan to follow at any time. Beneath the JTC sit the component commanders. The component commanders represent land, sea and air forces or could represent national contingents within a coalition. They 'size' each of the missions within a plan and delegate operational command to an appropriate intermediate commander in the party's hierarchy. For example, if the mission were suitable for a division then the responsibility for conducting the mission would be applied at the divisional level.

It is the intermediate commanders that represent this command chain with multiple levels representing (for example) battalion commanders up to corps commanders. They act upon the reports of their subordinates and manage their assigned mission as best they can. Should additional resources be required beyond what the IC can provide then they need to be requested from a superior.

Below the intermediate commanders are the entities themselves. Their command attributes are limited to prosecuting the activities that make up a mission and taking local decisions to enhance their survival or chances of success.

It is the combination of all these processes that allows the simulation to run without user assistance once a scenario has been scoped and developed. It is the development and testing of plans and mission sequences that requires the greatest input from the user. The majority of the processes related to sizing of missions and managing resources will be based on doctrine or operational experience.

2.6 Relationships

In existing combat models it has been traditional to represent only 2 sides of any conflict. This is a suitable assumption for most conventional battles as, regardless of the number of participants, they tend to fall into the categories of friend or foe. In non-warfighting operations this assumption is not valid, as there are often a large number of participants, none of which can be classified purely as hostile to each other. For example, in Bosnia there were 3 main armed factions, their respective civilian populations and the peacekeeping forces. In Somalia there were upwards of 24 warlords vying for control, the embattled civilians, the multinational peacekeeping forces and United Nations personnel, all of which were of strategic importance to the operation at one time or another. Very quickly it becomes obvious that any successful attempt to model non-warfighting operations requires a multi-sided approach. It was decided that each side in the simulation would be identified as a separate party and that the relationships between those parties would be used to describe their affiliations, rather than aggregating like-minded parties into distinct sides.

In accepting that a multi-sided model is required it is necessary to identify the relationships that will be required to describe the affiliations of each party. Again, in traditional combat modelling only one type of relationship is modelled, that of hostility between parties. In non-warfighting models a greater range of relationships is required. Research at Dstl Analysis has determined the minimum number of relationships required to represent basic inter-party behaviour is 5: Hostile, Uncooperative, Neutral, Sympathetic (co-operative) and Friendly.

Every entity within a party must share that party's relationships. For example, if a party of peacekeepers were neutral to the party of belligerents then every entity and commander within the peacekeeping party must share that view and see themselves as neutral also.

It was further recognised that a relationship between two parties does not have to be symmetric. For example, an NMO (Non-Military Organisation) may consider its relationship with a belligerent faction as neutral whereas that faction may adopt an uncooperative or even hostile stance in return. In the first release of DIAMOND, for simplicity, a party will always know the stance of other parties towards them, even if it is an asymmetric relationship. This leads to the possible relationship pairings depicted in Figure 8. Those marked with an asterisk are probably unstable relationships and would decay quickly to another relationship on the list once interactions begin between the two parties. However, this dynamic change in relationships is not represented in the current implementation.

	Hostile	Uncooperative	Neutral	Sympathetic	Friendly
Hostile	◆	◆	◆	❈	❈
Uncooperative		◆	◆	◆	❈
Neutral			◆	◆	◆
Sympathetic				◆	◆
Friendly					◆

Figure 8: The 15 Possible Relationship Pairings.

2.7 Negotiation

There are, in PSO, many types of negotiation that occur through the life of any operation. Mediation to resolve local disputes, negotiation to obtain a cease-fire and negotiation to obtain access are just a few. The types of negotiation the model is able to handle are:

- Negotiation for access
- Negotiation for support
- Requests for humanitarian assistance
- Requests for escort
- Requests for supplies (including demands and theft)

Each type of negotiation plays an important role in restoring normality or ensuring that potentially escalatory situations are resolved with the minimum amount of force by either side. As such aspects are an important part of PSO it is important that DIAMOND represents some elements of these interactions and their outcomes.

However, from the analytical community there has been very little related work on representing negotiation in a manner that is suitable for fast running simulation models. Consequently, DIAMOND has taken a two-path approach to representing some of the aspects of negotiation. The first path is the use of historical analysis and the second is to provide a mechanism that will allow the user to enter into the model the insights from Political-Military (Pol-Mil) gaming so that they can be interpreted dynamically by the model.

These approaches will allow DIAMOND to become the first stage in an evolutionary process for modelling cross party negotiation in PSO. Should either or both techniques prove successful then further development will follow.

Due to the time and expense incurred in conducting historical analysis only negotiation for access is represented with this approach. Roadblocks and other routeblocks are a major hindrance to peacekeeping operations, preventing or delaying free movement of peacekeepers, aid agencies and civilian traffic alike. They occur for a variety of needs, some through a genuine military reason to secure an area, some as a revenue source (tax and theft) and some simply because the protagonists are bored and see it as a means to exert their authority and pass time (Goodwin, 1999).

It is intended to conduct historical analysis on negotiation for access to identify the principal factors that affect the outcome. It is believed that current relationship, force ratio, rules of engagement and a unit's current mission are some of those factors. The input data to DIAMOND will be configured to match the important factors and referenced against a historical model derived from historical analysis. The output from this will be the time taken for a unit to negotiate and the probability of it successfully obtaining access.

There are some limitations in adopting this approach. The historical analysis conducted may be very region or context specific and may not allow for a fully generic approach. However, by ensuring that the historical analysis conducted focuses on areas or situations representative of the likely PSO contingencies there will be value in the data obtained for study use if not directly for DIAMOND itself.

The other types of negotiation that can be represented in the model will rely upon Pol-Mil gaming or expert judgement to define the conditions on which such a negotiation may produce a result. In these cases the time taken to conclude any negotiations will be represented and the model will represent the effect of a successful negotiation. Negotiation is confined to the missions represented within the model. For example, a party could request a transport mission or intelligence from another party but it could not negotiate a local cease fire in this version of DIAMOND (as there is no specific mission associated with cease-fires).

These other types of negotiation can be generically referred to as 'negotiation for co-operation', although that co-operation may in itself be as a result of a threat or other aggressive activity. The user defines whether co-operation on any mission could occur with another party for each possible relationship pairing and should co-operation be possible the analyst defines which missions they would co-operate on.

2.8 Combat

Combat is not intended to form a major part of any DIAMOND scenario. However as one of the main tasks of military forces in PSO in the provision of a secure environment there is always the potential for conflict. The representation of combat within the current implementation is mainly limited to its impact on ground forces, there is no representation of air-to-air or maritime engagements. This is not deemed to be a major limitation as the key focus of the majority of the scenarios that could be modelled in DIAMOND will be the land forces.

The basic combat process is similar to CLARION, the high-level land combat simulation used within Dstl Analysis. Unit strengths are measured using a static scoring method, BAMS (Balanced Analysis & Modelling System) and effectiveness data is based on the results of more detailed (lower-level) models. Combat is initiated when all of the following conditions are met:

- opposing units are either situated within the same node or within a user-defined distance along arcs
- at least one of these units is aware of the other (i.e. it is in its local picture)
- the force ratio is above the withdraw level of all units
- Rules of Engagement (ROE), and by implication the relationship between the opposing units, permit the engagement

After initiation combat continues until all the units on one side are defeated. If additional units join the combat then the situation is reassessed according to the same initiation criteria.

This basic combat process has been enhanced for DIAMOND to take account of the multi-sided nature of the model. This is achieved through the use of ROE. These also allow the representation of the deterrence or conflict prevention function of peacekeeping forces. ROE can be individually defined for every mission but the standard approach is to use a number of templates, each tailored toward specific mission types. These ROE are only known by the owning party – it does not know the ROE of other parties.

The ROE are defined by the relationship to other party and determine:

- can the unit open fire first or in response only
- who or what can be targeted e.g. civilian or military targets
- can the unit respond on behalf of a third party or facilities
- quantity of fire

The careful use of these ROE can allow the representation of situations unique to PSO:

- the interposition of a peacekeeping force between warring factions to stop conflict
- the deterrence effect of peacekeeping forces preventing conflict
- the provision of security to the civilian population

Figure 9 shows an example of how combat works within DIAMOND. The Red armoured units (“) advance into the node attacking the civilians and industrial facilities (which would be represented as ‘target’ facilities in DIAMOND) that are there. They do not attack the medical facilities as their ROE do not permit them to do this. The relationship between the Red and Blue forces (the infantry units, !, based at the node) is such that normally they would not engage each other. However, the ROE for the Blue forces allow them to go the defence of the civilian population and hence start to attack the Red forces. As a result of this, the Red forces switch their attention to the Blue forces as they present the biggest threat. The combat will end when either of the forces withdraws. If it is the Blue force that withdraws then Red will switch back to attacking the civilians and industry.

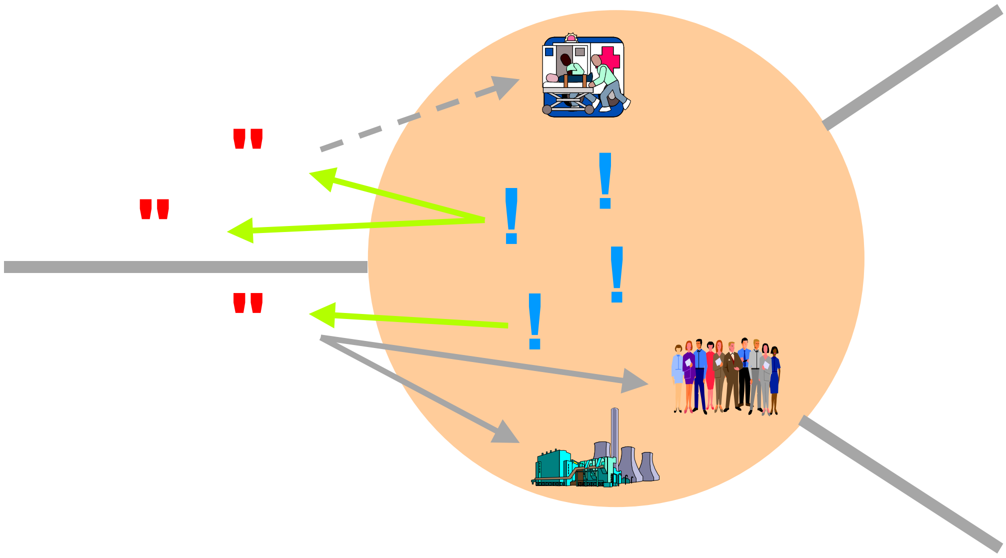

Figure 9: Example of Combat and the Impact of ROE.

The previous example could be modified such that the Red forces only attacked the industrial facilities. In this case, the ROE for Blue would not allow them to engage Red as the Red forces were not attacking civilians.

The example could also be modified to demonstrate the deterrence effect of a peacekeeping force. In this case the ROE for the Red forces could be set up to assume that Blue will attack Red, irrespective of Red’s other actions. Conversely, as Blue is a peacekeeping force, its ROE are set up to only act in self-defence or on behalf of the civilian population. Hence the Red assumption is incorrect but it is unaware of this. In this case, if the combat power of the Blue forces is sufficient then no combat will occur at all. If the combat power of Blue is insufficient then combat will occur as Blue would then be in a position of having to defend itself.

3.0 CONCLUSIONS

In summary, DIAMOND has been designed specifically to tackle OR questions relating to high-level defence policy and force development issues. Once developed, validated and populated DIAMOND will allow the OR community to examine these areas economically and quickly and act as a focus for the application of other tools, techniques and data collection. Where possible the design has been kept firmly rooted in accepted and validated modelling techniques and driven by known data sources. However, to obtain as full a coverage of the PSO domain as possible it has been necessary to develop new techniques and mechanisms and cite the requirement for new classes of data or algorithms to be developed. As our understanding of the PSO domain evolves so too will DIAMOND to take advantage of any new work and insights.

AUTHOR BIOGRAPHY

Peter W. Bailey is the Study Leader for the DIAMOND model at Dstl Analysis. Prior to taking up his current post, he was one of the analysts in the Operational Analysis Branch at HQ ARRC (Allied Command Europe Rapid Reaction Corps) and deployed with that HQ to Kosovo in June 1999.

Command and Control Assessment using the German Simulation System FIT

Hans Jürgen Rech
Industrieanlagen-Betriebsgesellschaft mbH (IABG)
Einsteinstr. 20, D-85521 Ottobrunn
GERMANY
+49 (89) 6088 – 2587
rech@iabg.de

ABSTRACT

*The simulation system FIT ("**F**ührung und **I**nformations-**T**echnologie" = Command and Control and Information Technology) was defined and implemented to meet the requirements of the analyses of command, control, and communication.*

The paper gives an overview of the simulation system as well as its application for the assessment of different command and control means, systems, and organizations and also communication facilities, installations, and systems.

To analyze the interaction between the C2 & CI structure and the outcome on the battlefield FIT can be federated with existing combat and recce simulation systems.

***Key Words**: Command, Control, Communication, Situation Map, Decision Making, Workflow in CPs.*

1.0 INTRODUCTION

The German simulation system FIT (*"Führung und Informations-Technologie"*) comprises models to cope with command and control (C2) organizations, C2 procedures, and C2 means, including communications. Therefore, it can be used as a stand-alone systems as well as a C2 & CI federate within embedding combat or reconnaissance simulation.

FIT has been design to meet the requirements of the German Army within the domain of command and control and C2 support to:

- Analyze and Evaluate the influence of evolution and progress of C2- and CI-systems
- Support the Planning of C2 for specific operations
- Model and Analyze Operations of C2- and CI-systems during missions.

The warfighter, armed forces offices, schools, as well as respective procurement agencies can be supported by conducting the necessary operational analyses. The application also can bridge the gap between the warfighter and the procurement office, developers and implementers in industry, planers and operators. By taking into account the different requirements and making the interdependencies obvious in respective simulation runs, the different stake holders get a more holistic view of the C2 problem and the influence of their decision than it would be the case without such a common tool. The German Army Office (*"Heeresamt"*) therefore distributed the system to potential users within the Department of Defense, the Army Office, and Schools of the Army.

Paper presented at the RTO SAS Symposium on "Analysis of the Military Effectiveness of Future C2 Concepts and Systems", held at NC3A, The Hague, The Netherlands, 23-25 April 2002, and published in RTO-MP-117.

Within the domain "Training and Exercises" the FIT system is planned to be used as a computer assisted exercise (CAX) tool for command and control support troops. It is planned to use the system:

- in stand alone versions at the respective school,
- embedded in a closed combat simulation to be able to train within a synthetic operational environment comprising all relevant forced (simulated), as well as
- embedded in the overarching CAX system of the army to be trained together with forces to support.

Within the domain of "Support to Operations" there is a twofold use of the FIT system:

- FIT can be used for full mission rehearsals and extensive C2 after action analyses, including what-if analyses and online support for C2 improvement.
- FIT can be used for the implementation of realistic command agents to be used for adequate generation of orders for the simulated forces in closed combat simulation systems to be used for alternative courses of action analyses.

2.0 (GE) COMMAND AND CONTROL PROCEDURES

The exercise of command that is the process through which the activities of a military force are directed, coordinated, and controlled to accomplish the mission. This process encompasses the **personnel, equipment, communications, facilities**, and **procedures** (C2 System) necessary to gather and analyze information, to plan for what is to be done, and to supervise the execution of operations.

The Command and Control (or Troop Leading) Cycle is a sequence of activities which comprises the following for phases:

- Assessment of the Situation
- Planning
- Issuance of Orders
- Control

Assessment of the situation is concerned with **gathering**, organizing, storing, presenting, comparing, **analyzing**, and evaluating information with respect to the own and enemy situation. The assessment of the situation ends with a **statement about the situation of the enemy**, the own troops, and the environment.

The **estimate of the situation** as the first step in the planning phase prepares the decision. All circumstances of the situation affecting the realization of the given order are analyzed and evaluated. The resulting **possibilities for alternate courses of action** are balanced against each other. This consideration of all factors related to an issue involving alternate courses of action arrives at a **decision** for a line of action intended to be followed by the commander as the one most favorable to the successful accomplishment of his mission. The operational plan shows (e.g. graphically) how the commander wants to employ his forces and assets. The operational plan is also a tool for the control phase in the command and control cycle.

The **orders** resulting from the planning phase are given to the subordinates.

Subordinates report on changes in their situation (own and enemy) during execution of the given order. Depending on the kind of changes this will cause a new start of the C2 cycle.

From this description of the C2 procedure we can identify methods and objects which must be available in a simulation system for C2.

Making a decision is one job within headquarters or command posts. There are other jobs, e.g. plotting enemy situation and own situation, generating orders, and transmitting information. All these jobs take time and all these jobs are executed in a well defined organization.

3.0 GENERAL ARCHITECTURE (INPUT / OUTPUT)

The following example is designed to make the reader understand the general context of the model a little bit better.

Basic for the work in a Command Post are Messages, Orders, or Information which must come from outside of FIT for example a combat or a recce simulation system. This kind of data is mainly related to changes in positions, combat power and results of recce missions. Orders might also come from an interactive user working with FIT.

Beside the dynamical input data FIT needs the Hierarchical and Procedural Organization. Different types of command posts are developed with an editor and stored in a so called Command Post Data Base (CP DB).

The model “Command Post” includes all the functionality we discussed in the previous section.

The transmission of messages and orders but also information within the command post is part of the Communication Model. The technical capabilities of the communication means are stored in a DB.

As the transmission might be jammed or disturbed by the enemy or the terrain, FIT also needs as an Input Information related to the terrain.

The output from FIT can be analyzed by itself but might also be used as an Input by a Combat Simulation System or a Reconnaissance Simulation System.

The combat simulation model gives changes of the states and results from reconnaissance missions from all employed elements as an input to FIT.

In the opposite direction the aim is to give orders or information requests to the linked simulation model.

Technically this coupling is realised as the exchange of files for two separate programs running in parallel on the same computer or via a network software (RTI based on HLA).

4.0 APPLICATIONS

The FIT system is well suited to deal with a great set of questions concerning command, control, and communication on various levels. The following fields of interest have been identified within discussion with the warfighters as well as within respective conceptual studies that now can be supported by qualitative analyses using FIT.

4.1 Command and Control Analyses

- Time constraints concerning command and control as well as command support.
- Comparison of ground truth and perception taking into account the usable information.

- Comparison of available information and needed information (necessity for better ISR means or improved ISR planning).
- Availability of information, including reliability, fidelity, timeliness, etc.
- Evaluating the effect of information operations over the whole spectrum.
- Evaluating the influence of additional means of command and control – e.g. decision support systems – on the improvement of the command process (time and quality).

4.2 Communications Analyses

- Analyzing and optimizing the information relations for various scenarios.
- Comparison of capacity and number of reports and orders.
- Evaluating the redundancy within the information flow.
- Evaluating the influence of communications on combat operations.
- Evaluating the introduction of new technologies on the information flow (e.g., introducing GPS for every system to reduce the location messages and thereby providing no longer used resources/ bandwidth for other messages).

4.3 Information Processing

- Impact of support means upon CI-systems.
- Impact of countermeasures.

5.0 THE FIT ARCHITECTURE

5.1 Modeling Command Posts

The main requirement for the modeling of the command and control process was the possibility to model different types of headquarters and command posts.

This following figure gives You a High Level Diagram for the modeling of Command Entities:

- A Command Entity may have a Command Post
- A Command Post may have one or more Cells
- A Cell is built by a Combat Entity; whereby the Cell gets position and vulnerability
- There may be Combat Entities not having built a Cell

A Cell consists of Methods:

- Situation Map,
- Decision Making,
- control the internal workflow and a
- for Information Interchange,
- and of one or more Communications Means.

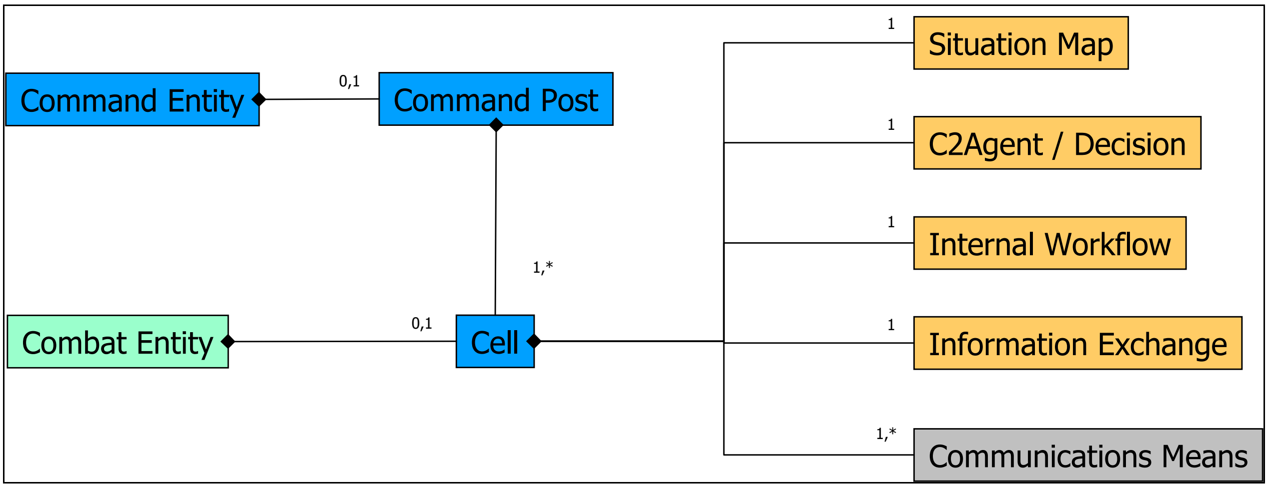

Figure 1: Modeling Command Posts.

5.2 Methods for Command Post / Cells

The following first two subsections deal with information processing, while subsection 3 and 4 are related to information transmission.

The actual influence of the information processing is actually limited to time delays, as no other specifications of effects to be implemented in a simulation systems could be given by the stakeholders. The time needed to execute a given task depends on the capacity of the command post respective the active cells. If the resources are already engaged in another process, the actual task has to wait for free capacities. If there is a bottleneck, the tasks will queue up which will be displayed and can be further evaluated.

5.2.1 Situation Map

Every command post has its own individual perception of the situation. Reports, orders, and information exchanges with the neighbors can be used to update this perception. Additionally, own sensors may be used to fill the gaps. As not only technical aspects can be taken into account, but also organizational aspects of the hierarchy within a command post (by modeling respective constraints within the workflow or when assigning the resources to the tasks), the evaluation beyond purely technical aspects becomes feasible.

The Module "Situation Map" is responsible for:

- check Consistency on Inputs
- update Tables (Combat Power, Needs,...)
- aggregate Enemy & Own Situation
- generate Enemy & Situation Rep
- give known Situation to Decision-Making

5.2.2 C2 Agent / Decision Making

The C2 Agent determines Orders for Subordinates, depending on the own Order, the capabilities of Subordinates, and the known situation (enemy and own forces).

Figure 2 gives an example for a C2 Agent. The red mechanized Company is given the order to attack an objective by tying to avoid contact with blue forces. The C2 Agent determines the course taking into account the terrain and the known situation. On its way to the objective to red company is attacked by a blue company. This blue company wasn't in the situation map of the red company before. This is a dramatic change of the situation for red and the C2 Agent determines a new course, remember part of the order was to avoid enemy contact.

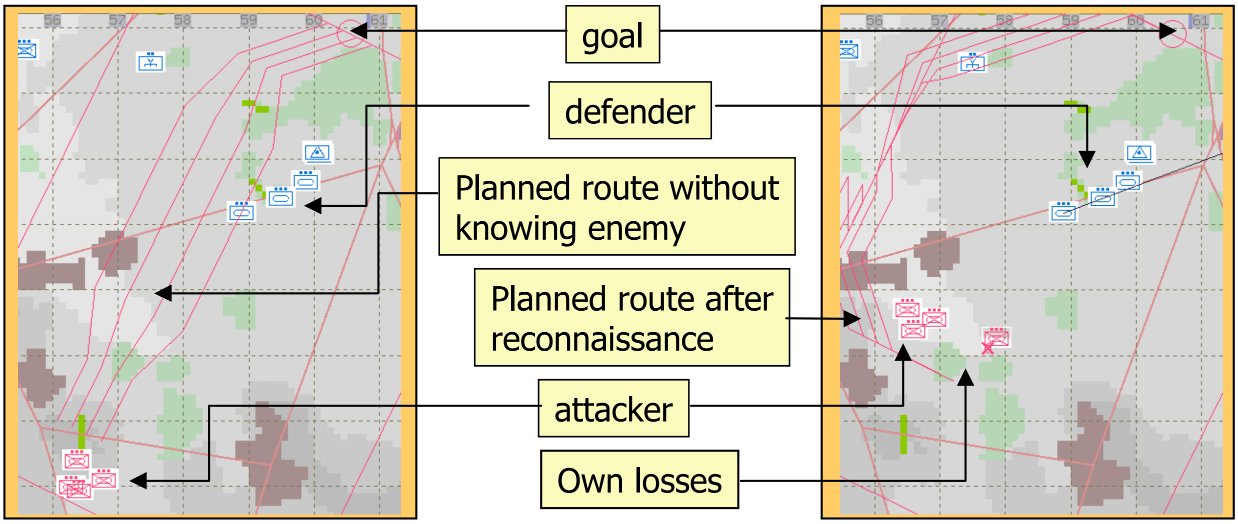

Figure 2: The C2 Agent "Attack".

5.2.3 Internal Workflow

The inner information structure of a Command Post (between Cells) is defined in form of resource dependent workflow. The internal workflow:

- controls the flow of information and activities within a CP
- initiates activities
- activates resources
- models the time needed for activities and
- models queues.

5.2.4 Information Exchange

However, there is not only an information flow between the cells of a command post. As already mentioned, every command post can send and receive reports and orders. In order to model this properly, a communication network has to be established. Within the FIT system, different and various communication means can be used: radios (broadcast as well as directional messages), digital links, telephone, telex, etc.

Based on their technical data a communication network is established enabling the information flow needed between the command posts. There may be several information transfer solutions between two points. It is part of the underlying decision logic of the chosen procedures to optimize the sharing of information.

For all command posts that share an information exchange requirement (IER), the communication means can be defined in detail via input parameters. Usable channels, bandwidth, capacity constraints, maximum distance, influence of the terrain (e.g., line-of-sight limitations) can be configured individually for every IER.

- Who sends information to Whom?
- What kind of information? (Orders / Requests / ENEMYSITREP / OWNSITREP)
- When?
- Type / Setting / Load of Communications Means.

5.3 Architecture

The hierarchy of the command and control organisation which is employed in a given scenario is part of FIT. It is important for FIT that within the force structures also the headquarters with the staff elements and the communication personnel is contained.

The staff elements than can build, dismantle, and deploy command posts for their headquarters.

The signal corps establishes and maintains the communication lines between command posts and within the command posts. For this it is necessary to determine the (logical) relationship between the cells of the command posts. That means to which other cells the information has to be transmitted. This is done automatically within FIT based on a direct comparison of input and output. If a cell A transmits a message which another cell B (within the same CP, a cell of the superior CP, a cell of an attached CP) can understand, FIT automatically establishes an information relationship between these two cells. The relations can be overwritten by the user.

Within the cells the main activities of command namely the Assessment of Situation, Planning (with Estimation of Situation, Decision), control of own and enemy situation, and the generation of messages are addressed. FIT takes into account the given hierarchical a procedural organisation, the time necessary and the man power and equipment available to perform these activities.

The transmission of Information is based on communication means with their technical data and actual state. The communication means are embedded in a technical communication network to determine lines of communication.

Figure 3 shows the overall architecture for FIT coupled to our simulation system for Surveillance, Reconnaissance and Target Acquisition, OSIRIS.

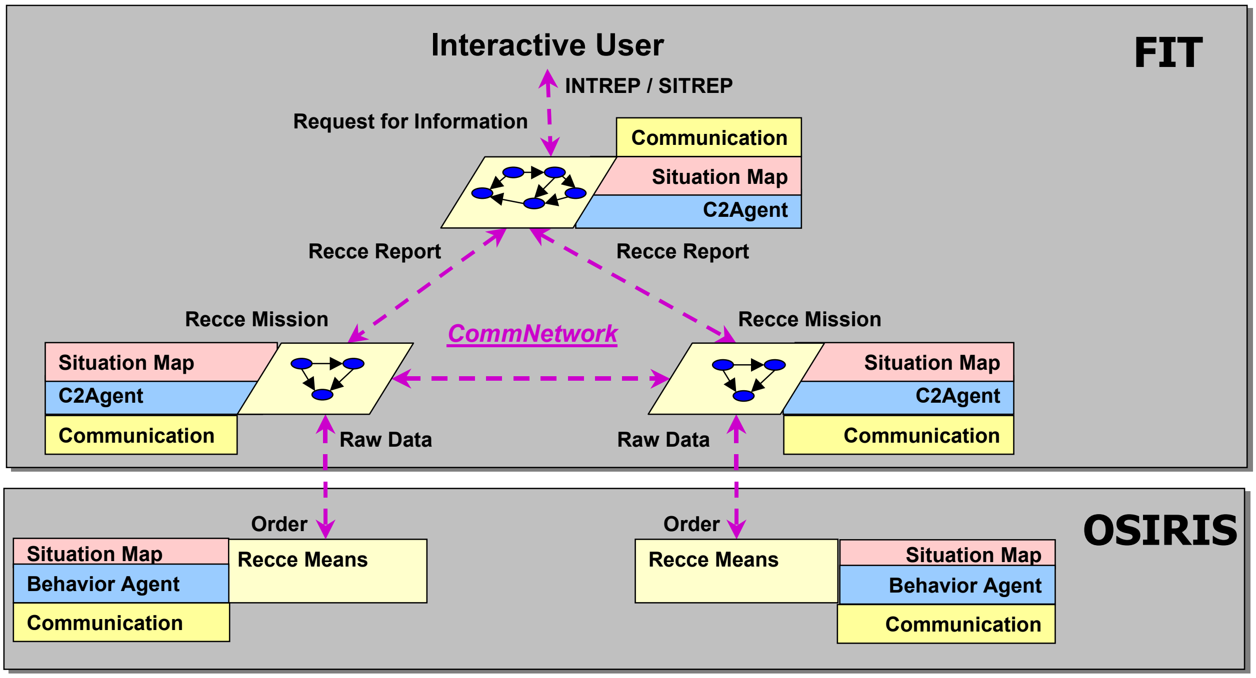

Figure 3: Architecture of the SimSys FIT.

5.4 Electronic Warfare and Information Operations

In the actual version, there are two ways to influence the FIT system.

On the one side, the connected combat or recce elements – i.e., the counterparts for command posts, cells, or communication means within the coupled simulation model – can be lethalized within the simulation. Within the FIT model, this would lead to the reduction of the respective capacity and resources. There is no attrition or suppression model in FIT, however, the reduction effect – i.e., a kill, suppression by the artillery down to 30%, etc. – can be calculated in the simulation model and handed over to FIT, where the influence of this reduction on the overarching command process is calculated.

On the other side, it is possible to use jammers to reduce the availability of information transfer means. A jammed frequency cannot be used for information transfer on neither side.

6.0 SUMMARY

To summarize, the FIT system enables the user to design command posts on all military levels in a very flexible way. It is also possible to model human behavior as well as group or organizational behavior implicitly as well as explicitly (team dependent time or efficiency constraints).

All simulated entities respective command agents, command posts, and headquarters have to share information. Within the FIT model, it is possible to model the interior as well as the exterior communication connections and means explicitly. The technical parameters of the communication means as well as environmental influences are taken into account. The communication model itself is again open, modular, and configurable.

In the moment, different radio types, satellite communications, Integrated Service Digital Networks (ISDN), and Local Area Networks (LAN) are modeled. The model takes the reports, messages, situation perceptions, etc. to be communicated between the entities and evaluate time and quality of the transmission. This allows the modeling of electronic warfare as well as information operations.

As far as the evaluation of similar efforts showed, the German FIT system is unique in its complexity as well as offering functionality. As it is a full functional HLA federate, it can be adapted to every simulation system to be used as a command agent for analyses of command and control, as a helpful tool in computer assisted exercises for the OPFOR as well as for neighbored troops, and – last but not least – as command agents in simulation systems to be used as decision support systems.

On behalf of the German Army Office, the FIT system is actually distributed to the various potential users within the Offices of the Army, the Department of Defense, and various Schools of the Army. Objective of this effort is not only to test and validate the various aspects of the model, but also to get respective input parameters specifying the view of the problem of the various instances. This is the first time in the history of the German Army that a model based data collection and evaluation approach is conducted. Beside the reusable data, the German Army Office hopes to increase the quality of harmonization between the different views of the instances by introducing a common tool for structured analysis of the problem.

7.0 REFERENCES

[1] Dr. Andreas Tolk, Hans Jürgen Rech, Manfred Eberhard, *The German C3-Model FIT*, Paper 01F-SIW-011, 2001 Fall Simulation Interoperability Workshop (SIW), Orlando, Florida, September 2001.

[2] Manfred Eberhard, *Modeling of Command and Control*, Proceedings of the 39, Army Operations Research Symposium (AORS), Ft. Lee, Virginia, October 2000.

8.0 LIST OF ACRONYMS

CAX	Computer Aided Exercise
CP	Command Post
C2	Command and Control
CI	Communication and Information
DB	Data Base
FIT	Führung und Informations-Technologie
Recce	Reconnaissance

AUTHOR BIOGRAPHY

Hans Jürgen Rech is Head of the Department for "Simulation Support / Army Analyses" within the division for Force Planning, Exercise, Education, Operation at IABG, Ottobrunn, Germany.

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Cognitive-Based Metrics to Evaluate Collaboration Effectiveness

Dr. David Noble
Evidence Based Research, Inc.
1595 Spring Hill Road, Suite 250
Vienna, VA 22182-2228
USA
(703) 287-0312
noble@ebrinc.com

Dr. Michael Letsky
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217-5660
USA
(703) 696-4251
letskym@onr.navy.mil

ABSTRACT

Effective collaboration within culturally diverse multinational coalitions is essential in many military operations, especially in OOTW. Unfortunately, effective collaboration is sometimes difficult to achieve within any collaboration team. Because methods to improve collaboration, including selecting the right team members, creating the right type of organization, providing the right kind of training, and selecting the right types of collaboration tools are not fully understood, identifying effective interventions requires experimentation. Metrics, and especially cognitive oriented metrics that focus on team member understandings, are critical to such experimentation. Such cognitive-focused metrics can measure not only whether particular interventions are improving team effectiveness, but can also illuminate the cognitive reasons for the improvement.

This paper reports on a three-year research effort to develop, test, and apply such metrics. It describes a model-based strategy for selecting metrics, several models useful for metrics generation, eight classes of metrics for measuring collaboration effectiveness and the factors that contribute to this effectiveness, and the results of two metrics evaluations that demonstrated the practicality of applying the metrics in military experiments. The handling of human and organizational issues, scenario development, selection of metrics, and use of models followed the recommendations of the Code of Best Practice.

Key Words*: Metrics, collaboration, experimentation, models, cognitive.*

1.0 INTRODUCTION

Cognitive-based collaboration metrics measure how well each team member understands his missions, tasks, and teams, how well the team members work together, and how effective the team is in producing high quality timely products efficiently. Successful metrics will enable collaboration assessors to review what happens in a collaboration, and to understand the relationship between individual understandings, team behaviors, and team products. When collaboration and teamwork does not work well, a well-founded set of collaboration metrics can help pinpoint exactly where in the process a problem arose, and so can help suggest remedies to these problems.

This paper describes a set of proposed cognitive-based collaboration metrics. It describes the collaboration models that form the theoretical foundation for the metrics, describes the metrics themselves, and reviews the evaluation of the practicality and feasibility of the metrics in military experiments.

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We define collaboration here to be "the mental aspects of joint problem solving for the purpose of achieving a shared understanding, making a decision, or creating a product." This definition emphasizes the cognitive and problem solving aspects of collaboration, as opposed to other definitions that place greater emphasis on information sharing. For example, the Information Superiority Working Group (Alberts, et al, 2001) defines collaboration as "actors actively sharing data, information, knowledge, perceptions, or concepts when they are working together toward a common purpose and how they might achieve that purpose efficiently or effectively."

2.0 THEORETICAL FOUNDATION – COLLABORATION MODELS

A cognitive-focused theory of collaboration describes the mechanisms that connect team member understandings to team effectiveness. It accounts for how the quality, completeness, and alignment of team members' understandings impact team performance and the quality of team products. The cognitive-based models of collaboration describe the theory.

Because there are many different factors to consider in understanding these connections, it is awkward to represent all of these factors in any single model. Instead, it is more practical to develop separate models that address different factors. These models do not present competing or conflicting interpretations of collaboration. Instead, they complement each other, each clarifying different aspects of collaboration. Five different collaboration models have contributed to development of the cognitive-focused collaboration metrics. These are the models describing teamwork and "taskwork," planning-execution feedback for both teamwork and taskwork, the interplay between teams whose members that oscillate between working separately and gathering as a team, the relationship between cognition, tasks, and products, and the importance of "transactive memory" as a key intervening variable. The first three of these models are described in the Phase 1 SBIR report (Noble, et al, 2000). The remainder are described in the metrics evaluation report (Noble, et al, 2001).

2.1 Teamwork/Taskwork Model

This model (Figure 1) describes the framework for organizing the different activities that teams must do. It distinguishes "teamwork" from "taskwork," terms that we have adopted from the UK CP-21 project. Taskwork is the work that the team must do to accomplish its mission, ignoring the coordination and other additional work that arises from working as a team. Teamwork is the additional work that the team must do in order to function as a team. It includes deciding how to partition the work among team members, how to coordinate their efforts, and how to adjust the team when necessary.

	Teamwork Organize and maintain the team	Taskwork Develop the product
Prepare	**Organize for teamwork** • Agree on goals • Identify tasks • Assign roles • Develop schedule • Identify interaction criteria and methods	**Develop mission plan** • Analyze mission • Identify tasks • Allocate tasks • Develop schedule • Assign resources • Identify constraints • Develop contingencies
Execute	**Attend to team health** • Monitor team processes • Cue and alert to possible problems • Diagnose nature of team problem • Reengage "organize for teamwork"	**Execute mission plan** • Monitor • Assess situation • Decide on needed plan adjustment • Issue directives • Execute / develop products

Figure 1: Teamwork/Taskwork Model.

This model enumerates and organizes many of the functions that teams must do. Because each of these functions can be important in collaboration under some circumstances, each requires metrics. For example, the model specifies that when teams organize for teamwork, they first need to agree on goals. Therefore, the model implies a need for metrics on the extent that people agree on goals and on the efficiency of the processes by which they reach agreement.

2.2 Planning/Execution Feedback Model

This model (Figure 2) builds on the teamwork/taskwork model. It emphasizes the importance of monitoring and adjustment for both teamwork and taskwork. In the case of taskwork, this corresponds to the normal feedback that occurs during plan execution. Commanders monitor the progress of a plan to determine if the plan will still enable them to achieve their objectives. If it does, they continue to execute the plan. If it does not, then they adjust the plan so that it will. Similarly, when a team is working together, the members need to monitor the team organization and processes, and to make adjustments to the team when needed. Common adjustments are to provide additional help to team members' who are overloaded, to supplement the expertise of the team, or to reassign roles to leverage team members' skills better.

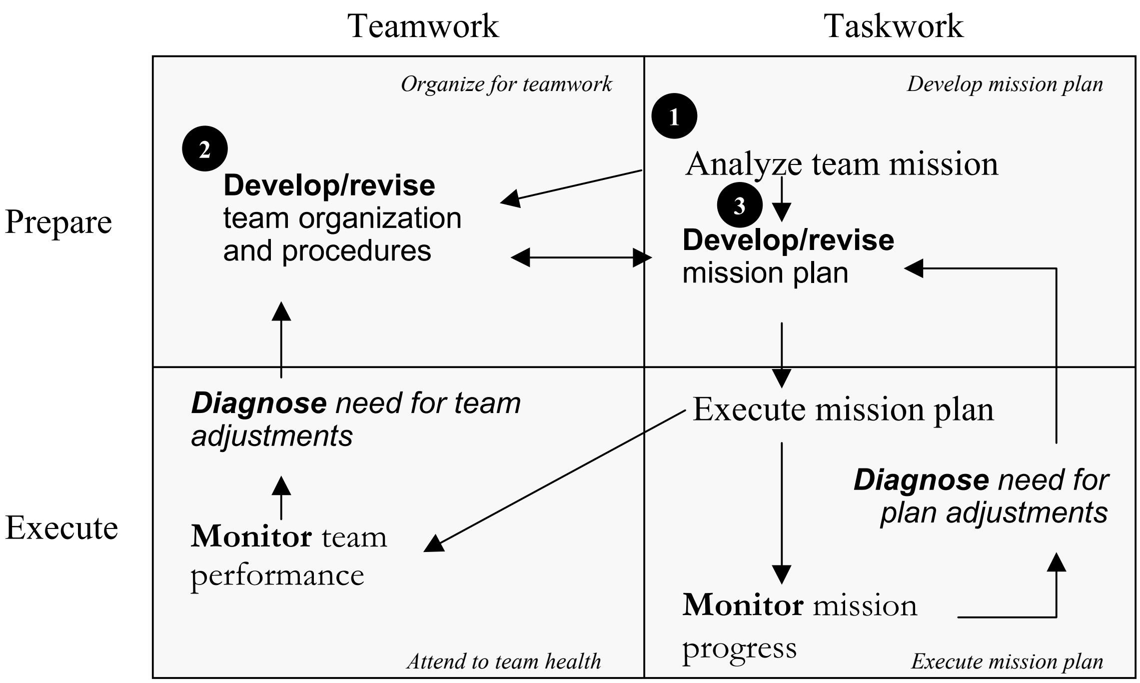

Figure 2: Planning/Execution Feedback Model.

This model implies the need for metrics on how well teams monitor their mission and team performance. Metrics for taskwork – the mission performance – have long been recognized as important in measuring command and control effectiveness (Hayes et al, 1983). This model emphasizes the need for an analogous set for measuring the feedback processes concerned with team health. For example, it suggests such metrics as time to detect that a team member is overworked and requires backup.

2.3 Individual-Team Interplay Model

The framework in the previous two models applies to every collaborative team. The individual-team interplay model (Figure 3) applies to only some types of teams. It describes the interactions important in teams such as collaborative planning groups. In these teams, team members occasionally meet synchronously as a full team to discuss and resolve issues and to adjust individual tasks. After this meeting, the individual team members separate to work on their separate tasks.

When meeting synchronously, the group exchanges information about team and task issues to develop a consensus. Figure 3 lists several different types of information exchange that frequently occur. These include distributing information, discovering differences, brainstorming, critiquing and enriching each other's ideas, guiding, and negotiating, and making decisions.

After the meeting, team members separate to work on their individual tasks (left side of Figure 3). In performing their tasks, they continually make decisions about what they should do. Figure 3 represents this individual behavior by listing seven cognitive functions important to decision making. Though not meeting synchronously as a whole team, team members do not work in isolation. They interact by sharing documents and other computer products (visualizations) and by talking with each other. Occasionally, one or more team members will decide that the whole team needs to meet again. Team members discuss an agenda and then separately prepare for the meeting.

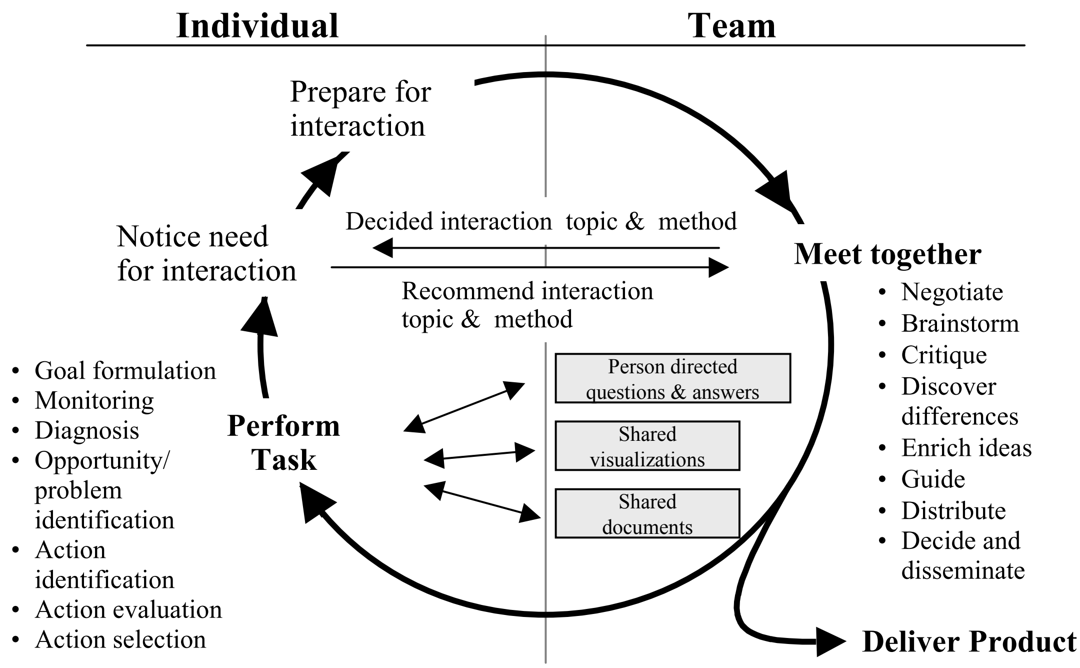

Figure 3: Individual-Team Interplay Model.

This cycle of team meeting and individual task performance continues as each team member develops and assembles the parts of the product he is responsible for. This process ends when the team delivers its final product.

This model lists the principal individual and group cognitive processes, each of which will sometimes be important to measure. The first EBR report on collaboration (Noble et al 2000) listed metrics for each of the cognitive steps in decision making (e.g., goal formulation, monitoring…), both for taskwork and for teamwork. The model also identifies some of the key synchronous team meeting processes that need to be measured. For instance, a metric for discovering differences could be the number of inconsistencies between people's understandings that nobody on the team is aware of.

2.4 Coupling Cognition, Behavior and Products

The Cognition-Behavior-Product model (Figure 4) emphasizes the nature of the relationship between individual and team understandings, individual and team behaviors, and individual and team products. It makes three important contributions: that team understandings, behaviors, and products must be mediated by individuals, that task quality and understandings affect each other, and that it is critical to measure individual task performance to assess collaboration effectiveness.

This model emphasizes that team cognition, team behaviors (the items listed under "meet together" in the individual-team interplay model) and team products connect only through individual efforts. For example, information exchange may be needed when different team members interpret team goals differently (differences in understanding are part of team understanding) and are aligned by discovering differences, clarifying ideas, and negotiation (team behaviors). However, this clarification only occurs when one or more team members individually realize that there is a cognitive difference that's important to address, and when each individual engages in the behavior necessary to address it.

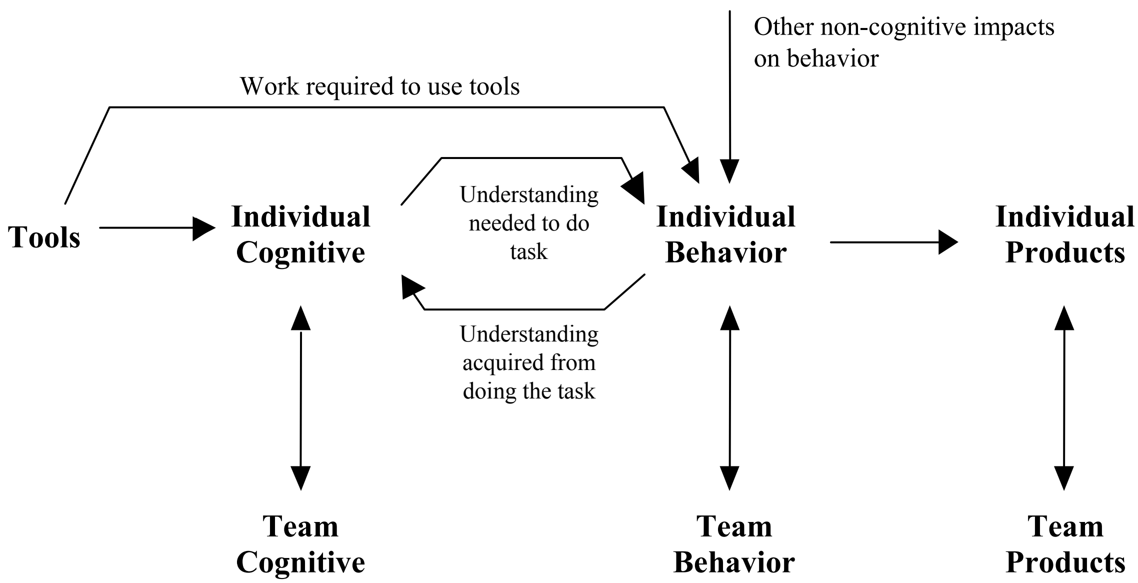

Figure 4: Cognition-Behavior-Product Model.

The second important feature of this model is the bi-directional relationship between an individual team member's understandings (individual cognitive) and his task performance (individual behavior). The forward direction, from understanding to task, is obvious. People who did not understand a task well enough to perform a task well will usually perform poorly. The backward direction is less obvious, but very important to understanding the dynamics of collaboration. That is, people who don't perform a task adequately will fail to acquire the understanding that doing the task well would provide. If that understanding is needed to support subsequent related tasks, the team members would then also fail to perform those tasks well, which in turn would undermine performance on additional tasks. Hence, failure to understand what's needed in order to perform an early task well can set up a chain reaction that undermines a long sequence of additional dependent tasks.

This model points out that individual task performance mediates understandings and product development. Accordingly, it stresses the importance of measuring task performance, to include how well a task is accomplished and adherence to the task schedule.

2.5 Transactive Memory Model

The transactive memory model (Figure 5) for collaboration has been developed and tested over the past fifteen years by team researchers, Moreland, Argote and Ingram, from the University of Pittsburgh, Carnegie Mellon University and Columbia University, respectively (Liang et al, 1995; Moreland and Myaskovsky, 2000; Argote and Ingram, 2000). Because of its emphasis on individual and team cognition and its strong empirical foundation, this model has been especially useful in identifying powerful collaboration metrics.

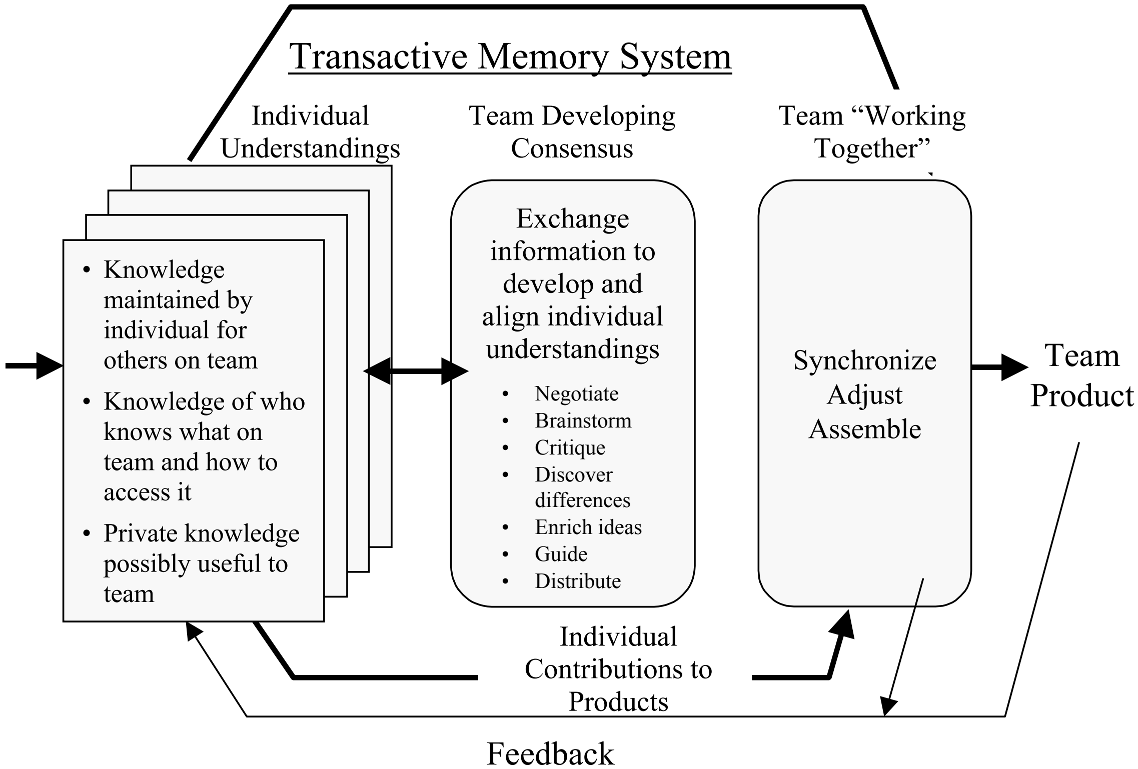

Figure 5: Transactive Memory Model.

The transactive memory itself consists of the collection of individual understandings and the team mechanisms to exchange information and so update these individual understandings. The individual understandings include all of the understandings about teamwork and taskwork pointed out in the teamwork/taskwork model. These include understandings about how to do the tasks required to perform the mission, understandings about the status of the situation and task, understandings of how the team is organized to function, and understandings about how the team is actually functioning now. It includes the common ground elements such as understanding of other team member's capabilities, workload, and knowledge.

In the transactive memory model, every team member is not expected to know everything. Instead, the knowledge is distributed throughout the team. As indicated in Figure 5, the model classifies individual understandings in terms of their relationship to the understandings of other team members. This classification emphasizes how team members leverage each other's knowledge. The classes shown in Figure 5 are the knowledge that individual maintains for team, knowledge about what others maintain for the team and how access that knowledge, and private knowledge that the individual should share with others if that knowledge becomes relevant to the team. Team members also have a "meta-knowledge," an assessment of the adequacy of their knowledge. In addition, they have an assessment of what they believe the team as a whole has decided.

The "team developing consensus" block includes the same elements as the "meet together" function in the "individual-team interplay model." In this model, however, the purpose and effects of these interactions are to update and align the individual understandings in the transactive memory system.

Transactive memory appears to be a powerful intervening variable for collaboration. The transactive memory literature has shown that in those cases examined (e.g., team training methods) the state of the transactive memory can account for (statistically) all of the effects of the experimental manipulation (Liang et al, 1995).

If this finding should generalize, then the transactive memory suggests a powerful class of cognitive collaboration metrics. This is the completeness and accuracy of a team's transactive memory, compared to what the transactive memory needs to be in order for the team to interact effectively. If, as the model suggests, the purpose of team member information exchanges are to create this needed transactive memory state, then the effectiveness of these exchanges may be assessed in terms of their impact on that state.

This last point, that the primary purpose of information exchange within a team is creation of the transactive memory that a team needs to carry out its tasking effectively, has great significance to metrics for collaboration. It suggests that measuring the amount or type of communication that occurs in a team is not particularly useful for understanding teamwork, unless that measurement can be related to its impact on the team's transactive memory.

3.0 COGNITIVE-FOCUSED COLLABORATION METRICS

Because teams collaborate for many different reasons and work together in so many different ways, there are a large number of potentially useful metrics. Figure 6 organizes these diverse metrics into four individual and team categories implied by the Cognition-Behavior-Product and Transactive Memory models. The following material describes the metrics in each of these categories, starting with the products and working toward understandings.

	Understandings	**Information Interactions**	**Task Performance**	**Products**
Individuals	Individual Understandings	Individual Information Interaction Support	Individual Task Performance	Individual Products
Teams	Team Understandings	Group Information Interactions	Teamwork	Team Products

Figure 6: Categories of Collaboration Metrics.

3.1 Product Metrics

These metrics measure product quality and timeliness, and the efficiency with which they are produced. They are the "proof of the pudding" metrics, for teams normally should not be designated to be effective unless they can produce a good product efficiently.

Metrics for products produced by teams are the same as those produced by individuals, for the measurement of product quality should not depend on how the product was produced. In command and control, typical products are situation assessment briefings, plans, and decisions. The quality of many of these, like plans and decisions, are difficult to measure because there is usually not a known "book solution" that can serve as a standard for correctness and completeness. Though measuring such abstractions is challenging, EBR has been doing so successfully for more than a decade. HEAT (Hayes et al 1983) describes many of these metrics.

Examples of product measurements are the quality and timeliness or a situation assessment briefing and the efficiency with which it's produced. Timeliness is product creation time relative to a deadline. Team efficiency is the total person hours required to complete a product.

Situation assessment quality has been measured by comparing team member's assessments to the assessments of experts made under ideal conditions. The metrics measure the correctness of team member's situation assessments in such categories as identity, location, and capabilities of own, neutral, and adversary forces; adversary and own opportunities and risks; adversary intentions and possible courses of action; and key environmental factors.

3.2 Task Performance Metrics

These metrics measure the processes for creating and assembling products. When applied to individual team members, they measure task performance, schedule adherence, workload, level of engagement, and flexibility. When applied to the team, they measure how well the team synchronizes, adjusts, and assembles its products. These metrics can be highly diagnostic of overall team effectiveness, with significant impact on the team product quality and efficiency metrics. Tables 1 and 2 summarize these metrics applied to individuals and teams.

Table 1: Metrics for Individual Task Performance

Issue Metric Addresses	Metrics
Overall performance	Fraction of tasks not addressed Thoroughness with which a task is done Correctness of task process employed
Schedule adherence	Number of tasks completed early and late Amount of delay in start time If completed late, how late Number of tasks out of order
Workload	Fraction of time team member is idle Fraction of assigned work not completed when no idle time
Level of engagement	Fraction of time team member devotes to task
Flexibility	Fraction time schedule is adjusted when needed Fraction time type of task is adjusted when required Fraction of time nature of task product is changed when required

Table 2: Metrics for Team Performance Emergent Behaviors

Issue Metric Addresses	Metrics
Team agility	Time required to note that team needs to adjust Fraction of time that adjustment is attempted when needed Effectiveness of adjustment
Synchronization	Average delay in starting a task because precursor tasks were delayed Diminishment of desired effect because of imperfect synchronization
"Fibrillation"	Fraction of preliminary individual products never used Fraction of individual products needing revision before they can be used

There are two categories of task performance metrics at the team level. The first type of metric aggregates the individual task performance metrics. It might, for example, take the average of team members' workloads. The second type measures emergent team behaviors. These are behaviors that apply to the team as a whole, but cannot be defined at an individual level. An example is "fibrillation," in which there is a substantial amount of work being done by individual team members, but the work does not contribute in a coherent way to an overall product.

3.3 Information Interaction Metrics

These metrics measure the adequacy of brainstorming, negotiating and the other processes that the team employs to acquire the required shared understandings and team consensus. At the individual level, these metrics measure individual contributions in support of developing the group understandings and consensus. At the team level, they measure the effectiveness of various group processes themselves.

The individual level metrics focus on the effectiveness of transfer of meaning, on the extent that each team member acquires the right information from an appropriate source, and on the extent the he provides the needed information to the appropriate recipient. Table 3 summarizes several of these metrics.

Table 3: Metrics for Individual Team Member Information Interactions

Issue Metric Addresses	Metrics
Information acquisition	Fraction of time correct team member is asked for information
Information provision	Fraction of time "private information" needed by group is provided
Transfer of meaning	Fraction of time information needed by others is provided in a way that could be understood without the need for clarification

The team level information interactions address how well the team as a whole functions as an assessment and decision making entity. An effective team will identify good lists of candidate assessments and actions and will evaluate these lists considering a full range of relevant criteria. Good teams will avoid the information filtering and biased evaluation criteria documented to arise in "Group Think" (Janis, 1972). Table 4 provides examples of metrics in this category.

Table 4: Metrics for Team Information Interactions

Issue Metric Addresses	Metrics
Brainstorming	Completeness of alternative situation interpretations considered by group Complete of decision alternatives considered by group Completeness of decision criteria considered by group
Negotiating	Fraction of time people advocating conflicting actions find an action acceptable to all parties
Critiquing and idea enrichment	Fraction of people on team responsible for an area asked to comment on products in that area Fraction of time spent in a meeting not relevant to own responsibilities and not contributing to other
Discovering differences	Fraction of differences in understanding identified
Distributing	Fraction of the people who should receive information that actually receive the information Average fraction of irrelevant information received by each team member

3.4 Cognitive Metrics

Cognitive metrics measure the extent to which the team understands what it needs to understand in order to be effective. That is, they measure the adequacy of a team's transactive memory system.

The EBR report, "Metrics for Evaluation of Cognitive Architecture-Based Collaboration Tools, (Noble 2000) identified hundred of cognitive metrics for individual team members. These are organized in terms of teamwork and taskwork for seven decision making processes: goal formulation, monitoring, situation diagnosis, opportunity/problem identification, identification of candidate actions, evaluation of these candidates, and action selection. They address all of the elements of transactive memory, such as knowing what team member possesses needed team knowledge and knowing how to access that knowledge. Table 5 lists a few of these metrics.

Table 5: Cognitive Metrics for Individual Team Members

Issue Metric Addresses	Metrics
Taskwork: Understanding commander's intent	Correctness of team member's understanding of commander's intent
Taskwork: Situation understanding	Correctness of team member's estimate of adversary goals
Taskwork: Schedule and process information	Correctness of knowledge of deadlines
Teamwork: Knowing team member responsible for various kinds of knowledge	Correctness and completeness of knowledge each team member is responsible for
Teamwork: Identify team member overworked and likely to not finish task on time	Correctness of team member's estimate of workload for those team members producing a product needed as input to that team member

There are three different types of team level cognitive metrics: roll-ups, team coverage, and alignment. Roll-ups are averages of the team member's metrics, averaged over team members. Team coverage concerns gaps in team knowledge or maximum expertise of knowledge within a team. Alignment concerns the extent that team members' understandings are consistent.

4.0 EXPERIMENTAL DEMONSTRATION OF METRICS PRACTICALITY

The metrics identified in the previous section must be feasible to be useful. That is, it must be practical to collect the data to compute the metrics in the experiment environments in which it is desired to measure collaboration effectiveness. EBR performed two evaluations of the above metrics, piggy backing on experiments at PACOM at Camp Smith, Hawaii and at JFCOM at Suffolk, Virginia. Both of these experiments confirmed the feasibility of the metrics.

4.1 Evaluation Issues

The practicality of these cognitive-focused collaboration metrics may be limited by their large number and by collection constraints at operational venues. In addition, use of some of these metrics may be hindered by the low observability of the phenomena being measured; by the large amount of data needed, and by their high level of abstraction. Because of these potential problems, the metrics evaluation sought to answer the following questions.

1) Does insight about collaboration require so many metrics that collecting the needed data to estimate this number is impossible?
2) Do the data collection constraints during experiments at military sites preclude obtaining the required data?
3) Does the low observability of cognitive metrics (e.g., measuring what people know) preclude collecting the needed data?
4) Is it possible to collect the volume of data needed to compute team level metrics which require measurements of all team members?
5) Are the team product metrics developed to measure C2 processes fully applicable to measuring collaboration products?

At the two evaluations, EBR tried out the metrics determine the extent that each of the potential problems impacts their utility in actual experiments. The ACOA MUA evaluated the first four of these metrics feasibility questions, providing affirmative answers in each case. The JFCOM experiment addressed all of the issues under more stringent data collection conditions, and also provided affirmative answers. In both cases, EBR's data collection goals were added to the objectives of larger evaluations previously planned for other purposes.

4.2 Evaluation at ACOA Military Utility Assessment (MUA)

The ACOA (Adaptive Course of Action) Military Utility Assessment is a formal evaluation event required for any technology developed as part of Advanced Concept Technology Demonstrations (ACTD). ACOA is a suite of integrated tools to support distributed collaborative planning at the CINC and JTF levels.

At the ACOA Military Utility Assessment a group of military and government civilian planners evaluated the effectiveness of an advanced distributed planning system being developed by the Adaptive Course of Action ACTD. These planners manned spatially distributed workstations that provided access to the ACOA collaboration tools.

Data collection. A contractor working as part of this ACTD planned and conducted this evaluation, and analyzed the results. EBR was invited to contribute two data collectors who were assigned to two of the workstations, and to contribute questions that were included in questionnaires presented to each participant at eight designated times in the two day evaluation.

EBR was limited to 2 to 5 cognitively focused questions at each of these eight prescribed points in the evaluation. As part of the data collection constraints, EBR designed these questions so that each could be answered within a few seconds. These questions probed the participants' understandings about issues important to task and team understanding. The taskwork questions asked about commander's intent, adversary goals, and plan elements and weaknesses. The teamwork questions asked about the responsibilities of people at the different workstations, how busy they are, and whether the team needed additional outside expertise.

Unlike the data collected through the questionnaires, which were presented on eight occasions to all participants, the metrics-related data was collected continuously but at only two workstations. These data focused on observable behaviors and conversations, but also included participant comments on current concerns and issues.

Results. Asking participants questions about their taskwork and team understandings was sufficient to compute both the individual and team level cognitive metrics on these subjects. While limited to only a few topics, the completeness and accuracy of their answers, as computed by comparison with an answer key, provided insight about their level of teamwork and taskwork understandings in general.

The observer notes on participant behaviors, conversations, and comments were sufficient to understand the relationships between task performance and their cognitive and non-cognitive causes. In fact, it was the analysis of these data that gave rise to the Cognition-Behavior-Product Model depicted in Figure 4. Table 6 summarizes these relationships for the evaluation participant playing the role of the operational planning team leader. Note that in ACOA confusion over how to use these new kinds of tools added to operator workload on several occasions.

Table 6: Summary of Impacted Behaviors and their Causes for the MUA Team Leader

		Cognitive Causes					Non-cognitive Causes			
	Total Impacts	Tool mechanics confusion	Tool concept confusion	Task/process confusion	Low awareness of other's activities	Judged not worth the effort	Machine requires extra effort	Waiting	Synchronization	Artificiality of environment
Task Impacts										
Low task quality	2		1							1
Not completed	5	1	1	2		1				
Cursory	3					3				
Delayed	4	1					2		1	
Out of order	2			2						
Increased workload	24	11	1	2	2		7			
Activity level										
low										
Engagement level										
low										
Total of Causes	41	14	3	6	2	4	9	0	1	1

4.3 Evaluation of JFCOM Presentation LOE

This second metrics evaluation was intended to be a more stringent test of the collaboration metrics feasibility. Like the ACOA MUA, the EBR collaboration metrics evaluation team was permitted to add questions to a questionnaire presented to participants every few hours. However, unlike the ACOA MUA, where EBR data collectors sat next to key participants and were free to ask questions throughout the experiment, the JFCOM experiment imposed the more typical experimentation constraints where observers were to be "flies on the wall" during the scenario execution. As described below, these constraints did not reduce the ability to collect cognitive data from questionnaires. However, they did reduce the ability collect behavioral data.

The JFCOM Limited Objective Experiments (LOE), held at JFCOM/JTASC in August 2001, compared the effectiveness of three alternative methods of presenting and interacting with situation information. In this experiment, 18 staff members from JFCOM were organized into three groups, each functioning as a collaboration team. Each member of each of these groups was assigned to one of six positions, and retained that position throughout the two weeks of the experiment. The positions were "chief of staff," "plans," "operations," "future information," "current information, and logistics." Each team worked together in a room dedicated to a particular presentation method, but members were separated by partitions to generate the effects of spatially distributed teams. Team members shared a large wall-mounted visualization and personal computer visualizations. They could communicate by voice or by e-mail.

Data collection. The experiment exposed each of the three groups to each of the alternative presentation methods. The experiment was divided into twelve time periods. After each period, each participant answered a questionnaire about the situation, and each of the three groups prepared a situation briefing. In the data analysis, the experiment analysts scored each individual questionnaire for correctness and completeness of situation understanding, using an answer key that represents expert understanding. The analysts also scored the team situation briefing using the same answer key.

Because the JFCOM experiment focused on the effectiveness of information presentations in supporting situation understanding, many of the experiment questions prepared by the experiment organizers were the same as those needed to test the cognitive metrics for taskwork.

Results. As in the ACOA experiment, this experiment demonstrated the feasibility of the metrics. The desired data were able to be collected and analyzed under the fairly restrictive constraints placed on the data collectors. This experiment also showed the applicability of product quality metrics to the products produced by teams.

Figure 6 portrays a particularly significant result from the JFCOM experiment – the strong confirmation for the substantial advantages of collaboration, with the data being consistent with the hypothesis that these advantages are mediated by the “transactive memory mechanism” discussed in Section 2.5. This figure compares for each of the three groups in the experiments the 1) the average situation understanding among team members, 2) the best individual situation understanding within the team, and 3) the quality of the team’s briefing describing the situation. As shown in Figure 6, for each group the team briefing was significantly better than the average situation understanding of team members, and was in fact significantly better than the best understanding of any individual team member. Note that the criteria for evaluating the briefings and the situation understandings were identical. Both were based on the same answer key and on the same scoring criteria.

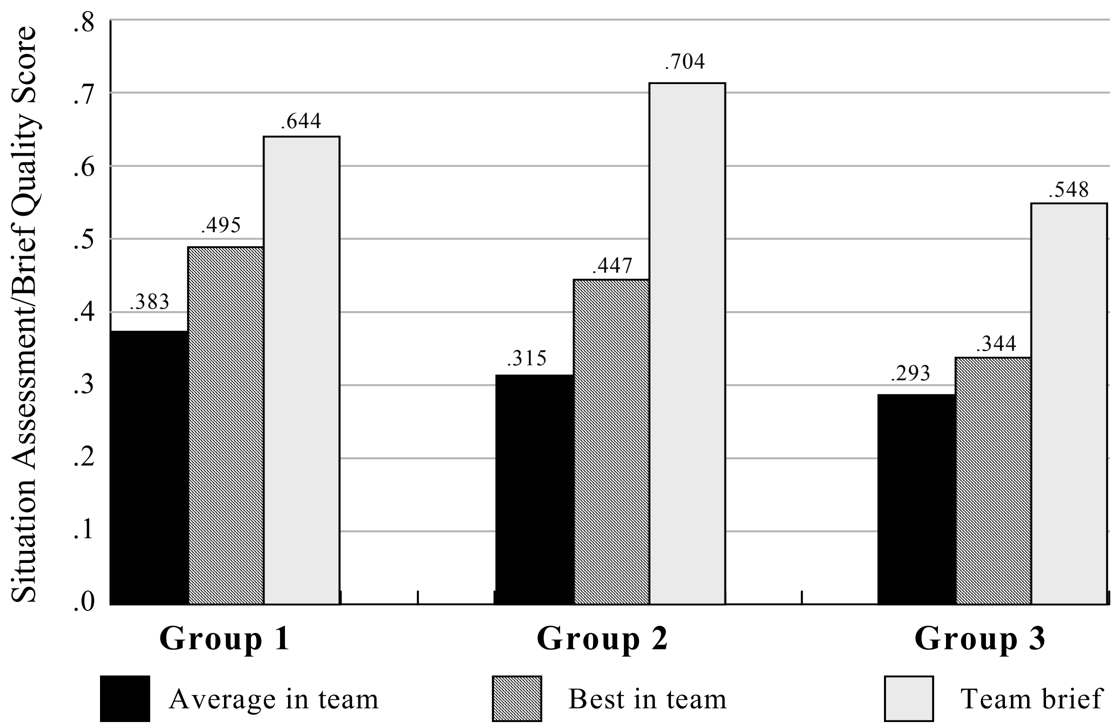

Figure 6: Measured Quality of Team Situation Assessments and Briefings.

Without looking at the data for "best in team," the improvement of the team brief over the average understanding had two plausible explanations. The first is that the best member did the brief for the rest of the team, not relying on or needing the input from the other team members. The second is that the team members pooled their individual understandings, with each team member contributing especially to his particular area of understanding.

Clearly, in this JFCOM experiment, the "best in team" data rules out the first explanation, because for every team, the team brief was significantly better than the best of the individual situation understandings.

This example shows not only that team cognitive metrics are feasible to collect and compute, but that these metrics support theory development and testing. These metrics clearly support the transactive memory model, for this model provides a very direct way to understand these results. This model asserts that a collaborating team divides up responsibility for knowing various facts and procedures among team members. Each team member knows who is responsible for a particular area and knows how to obtain that information from those team members.

The transactive memory mechanism can easily explain the results observed in this experiment. Because someone knows something about each subject, pooling team knowledge generates some information about each aspect of the situation. This generates the high briefing score. Because no one knows everything about the situation, the understanding of any one individual, including the best informed person, is less complete than that of the team as a whole.

5.0 CONCLUSION: APPLICATION OF CODE OF BEST PRACTICE

The cognitive-focused collaboration metrics measure individual and team understandings, information interactions, behaviors, and products. They are feasible to employ, and can not only measure team effectiveness but can provide insight into the reasons for effectiveness.

Development and evaluation of the cognitive metrics complied with the recommendations of the Code of Best Practice:

- *Metrics organization.* They are organized into a hierarchy of metrics types that address the quality of the overall team product as well as the effectiveness of the understandings and behaviors the contributed to developing the product.
- *Human factors*. They address an important human factors issue – the relationship between individual understandings and behaviors and overall team effectiveness.
- *Scenarios.* The scenarios used to evaluate the metrics were designed to exercise key factors expected to drive utility of the metrics.
- *Use of models*. They are informed, guided, and motivated by cognitive models of collaboration.

6.0 REFERENCES

[1] Alberts, David; Garstka, John; Hayes, Richard; and Signori, David; "Understanding Information Age Warfare", Command and Control Research Program, 2001.

[2] Argote, Linda; and Ingram, Paul; "Knowledge Transfer: A Basis for Competitive Advantage in Firms", *Organizational Behavior and Human Decision Processes,* Vol. 82 No. 1 (May 2000): 150-169.

[3] Hayes, Richard E.; Hainline, Mark; Strack, Conrad; and Bucioni, Daniel; "Theater Headquarters Effectiveness: Its Measurement and Relationship to Size, Structure, Functions, and Linkage", McLean, VA: Defense Systems, Inc., 1983.

[4] Janis, Irving; "Victims of Groupthink", Houghton Mifflin Company, 1972.

[5] Liang, Diane Wei; Moreland, Richard; and Argote, Linda; "Group Versus Individual Training and group Performance: The Mediating Role of Transactive Memory", *Personality and Social Psychology Bulletin*, Vol. 21 No.4 (April 1995): 384-393.

[6] Moreland, Richard; and Myaskovsky, Larissa; "Exploring the Performance Benefits of Group Training: Transactive Memory or Communication?", *Organizational Behavior and Human Decision Processes,* Vol. 82 No. 4 (May 2000): 117-133.

[7] Noble, David; and Buck, Diana; "Metrics for Evaluation of Cognitive Architecture-Based Collaboration Tools", Phase 1 SBIR Final Report, Evidence Based Research, Inc., 2000.

AUTHOR BIOGRAPHY

Dr. David Noble is a Senior Scientist at Evidence Based Research. He is currently conducting research on the cognitive foundations of collaboration, with the goal of developing theory-based guidelines for improving the effectiveness of collaboration teams. In the past Dr. Noble has conducted research on the cognitive-basis of situation assessment and decision making and on ways of measuring situation assessment and decision making performance. In addition, he has developed data fusion algorithms for decision aids to improve situation assessment and decision making. Dr. Noble received his doctorate in applied mathematics from Cornell University.

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The Relevance of Human Behaviour Representation in Future C2 Systems – Current and Future Research Approaches[1]

Dr. Alexander von Baeyer
IABG – IK 31
Postfach 1212
D-85503 Ottobrunn
GERMANY
+49-89-6088-2127
baeyer@iabg.de

ABSTRACT

The paper is divided into three parts:

1) *A general plea for more Human Behaviour Research in the area of military command and control taking into account the recent political and military developments.*
2) *A short discussion on German study projects about Human Behaviour Representation and Organisational Behaviour Representation.*
3) *A proposal for a comprehensive research plan for future analyses, based upon the LTSS on Human Behaviour Representation and the author's own research.*

***Key Words**: Human Behaviour Representation, Modelling and Simulation, Training, Operational Analysis.*

1.0 A PLEA FOR FOCUSED HUMAN BEHAVIOUR RESEARCH IN MILITARY COMMAND AND CONTROL

1.1 New Military Challenges

Post-Cold War history is characterised by two new military challenges:

1) Frequent peace support and humanitarian assistance operations, to be planned and executed by soldiers who where trained to fight.
2) Military operations against "asymmetric" threats posed by "irrationally" acting enemies, to be planned and executed by soldiers trained to fight against military organisations structured and trained on a more or less equal footing.

[1] This paper would not have reached its actual content and form without intensive discussions with Professor Reiner Huber of the Federal Armed Forces University Munich. His constructive critique and appreciation of Human Behaviour research problems have considerably improved the paper. Our collaboration is a good example of the interdisciplinary work which is indispensable for the assessment of C2 systems.

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These challenges require a new type of soldier. In analogy to the so called Revolution of Military Affairs (RMA) we may speak about a revolution in military qualifications. Both challenges have been met with some success.

- Peace Support Operations (PSO) are basically coalition operations with a wide variety of military and civilian “partners” in unstable environments. Special attitudes and skills are required in PSO. Intercultural and inter-organisational behaviour is about to develop, ethical standards are discussed, political sensibility has become a part of military training on lower command levels. However, systematic analysis and evaluation (i.e. research) is only at the beginning.
- Terrorism may be considered the epitome of the new threats. New approaches are required to fight terrorism some of which are being tested in the Anti-Terror War in Afghanistan: Highly mobile and small teams being part of a real time on-line command and control system and disposing of heavy fire power operate in an almost transparent three-dimensional battle space. What is the challenge of this new threat environment for human behaviour research and representation? Again systematic behaviour analysis and evaluation is indispensable.

So far, hardly any systematic research on these challenges has been undertaken. Whatever success may have been achieved in the field, the underlying doctrine may thus be temporary, awaiting the development of a sound theoretical basis and empirical back-up in order to be sustainable.

1.2 Definitorial and Scientific Framework

The scientific discipline addressing the new challenges to military personnel has become known as Human Behaviour[2] *Research*. Its application in the Modelling and Simulation community is called Human Behaviour Representation (HBR).

Human Behaviour is a *purposive reaction of a human being to a meaningful situation. Representation implies observable concepts and parametric definition* [1]. Human Behaviour *Representation’s* ultimate purpose is the “*optimisation”* of behaviour through testing behavioural hypotheses in simulation experiments thus generating behavioural modules, which are to be used in training, mission support and operational analysis. HBR covers essentially all human sciences, their interfaces with technical sciences and in particular informatics and computer sciences, respectively. However, HBR is not a subset of computer sciences, as (e.g.) agent based modelling, it rather entails the human sciences *par excellence.*

1.3 Objectives of Human Behaviour Representation

Since there are many individual sciences such as, for example, psychology, cultural anthropology, and cognitive ergonomics involved and the potential use of HBR is manifold (training, mission rehearsal, personnel selection), it is imperative to agree on its fundamental aims and structure in order to provide for effective access to resources (manpower and data) and to avoid duplication of efforts.

The *aims* of HBR research can be defined as:

- “optimal” *exploitation and allocation* of the mental capacities of military decision makers on *all* command levels
- “experimentation” with behaviour models in virtual environments throughout all major military activities.

The *structure* of HBR resembles that of interdisciplinary and applied research that requires the co-operation among the scientific disciplines involved as well as with the users of the research results.

[2] The term “behaviour” is used very broadly. “Behaviourism”, a school of psychological thinking, is not necessarily implied.

This is most importantly an *intra*-organisational task within the responsibility of the military customer. Any design of applied research *not* involving human sciences *and* technology *and* the user domain knowledge right from the beginning is prone to fail. This assertion may sound trivial, however, entails non-trivial organisational problems. The HBR team-building in military organisations needs high level support to be effective, because it requires the collaboration of scarce operational manpower and cuts across all command levels and many major commands.

1.4 Structure and Usage of HBR

There are two different kinds of behaviour: *intra*-personal "behaviour" and *inter*-personal behaviour. With the two new military challenges discussed above, four areas of HBR issues can be distinguished. Each of them entails distinct research issues, which need to be defined and structured based on a consensus of the disciplines and knowledge domains in question. The interdisciplinary collaboration begins with the definition of the problem.

The following research problem areas, regarded to be of some urgency:

- Impact of different *leadership styles* on the effectiveness of missions (in PSO, in conventional warfare and in asymmetric warfare, and about the implications of sudden changes in these mission paradigms).
- M*ental dispositions* and *training* to cope with the sudden change of mission paradigms (e.g. from PSO to full blown combat).
- G*roup-think syndrome*, for team decisions, especially when the group dynamics are not transparent, so that one does not know why a group reacts the way it actually does.
- The new kind of stressors and stress coping strategies in PSO and asymmetric warfare. There are, however, many individual stress research projects, but little is known about large scale (longitudinal and long term) research projects on complex, realistic cognitive challenges under stress in military environments [2].
- M*otivation* Structure of military leaders – along the lines of the so-called "Reiss-Profiles [3]". Motivation is the primary factor of decision making and acting. The Reiss-Profiles tell us (e.g.) that "Vengeance", "Family" and "Order" are the three highest motivational factors of the average middle-class American, whereas "Citizenship", "Power" and "Independence" rank lowest. Are there similar or different profiles in the military population?

Psychology is considered to be the core discipline for HBR. Important assertions of psychological research relevant for HBR can be roughly summarised as follows:

- The nature of knowledge acquisition is *constructivistic* [4]: Knowledge is socially shared model building in contexts. Every individual knowledge is context-dependent and defined by the individual and social history of the individual. This means: that HBR agents (i.e. models) must be programmed as *learning "automata"* socially interacting with other "models" and with a changing environment. Different agents must have different learning histories. Today, HBR methodology hardly acknowledges this requirement.
- Group behaviour research [5] aims at enhancing team effectiveness, at avoiding mistakes in intra-team communications, and at creating favourable team environments. For HBR this means that: modelling of group behaviour must address *shared group goals and group memory* as the primary entity to be modelled explicitly, and not merely group structure or what is often called "coherence".
- Decision making, or better, choosing between alternative courses of action, is the product of motivational, emotional and cognitive factors. It is not an outcome of "rational" choice such as

deciding between different probabilities of success, because the evaluation of probabilities is based on individual rationales and, therefore, implies a subjective act. The German study project presented next may well serve as an example.

2.0 GERMAN STUDY PROJECTS

So far HBR research in Germany was dealing with intra-personal decision making in PSO. It resulted in a new psychological concept of decision making in critical situation based upon which a process model of choosing among different courses of action was developed.

The model works with five major psychological constructs: motivation, schema-based action, self-efficacy, emotional stability (neuroticism-scale) and a reversed "Rasmussen scale".

Extensive tests of this model have demonstrated that individual behaviour described in these terms and its impact on critical situations, can indeed be modelled. Different individuals affect situations differently, and the model illustrates how this works in simulation.

The demonstration model is based on a typical PSO micro-scenario: apprehending and disarming a gun-man. Different options to act, e.g. negotiation or the controlled use of force, are chosen by the HBR module according to how the simulated person's psychological structure is defined. In addition, the demonstration model permits to generate circumstances when the situation may get out of control. Psychological effects, different courses of action and outer world effects (e.g. obstacles, stressors) as well as direct and indirect outcomes are modelled. The demonstrator proves that a *complex* psychological behaviour model can indeed be implemented in military simulation systems. Figures 1 and 2 provide an overview of the formal structure of a micro scenario and the HBR module.

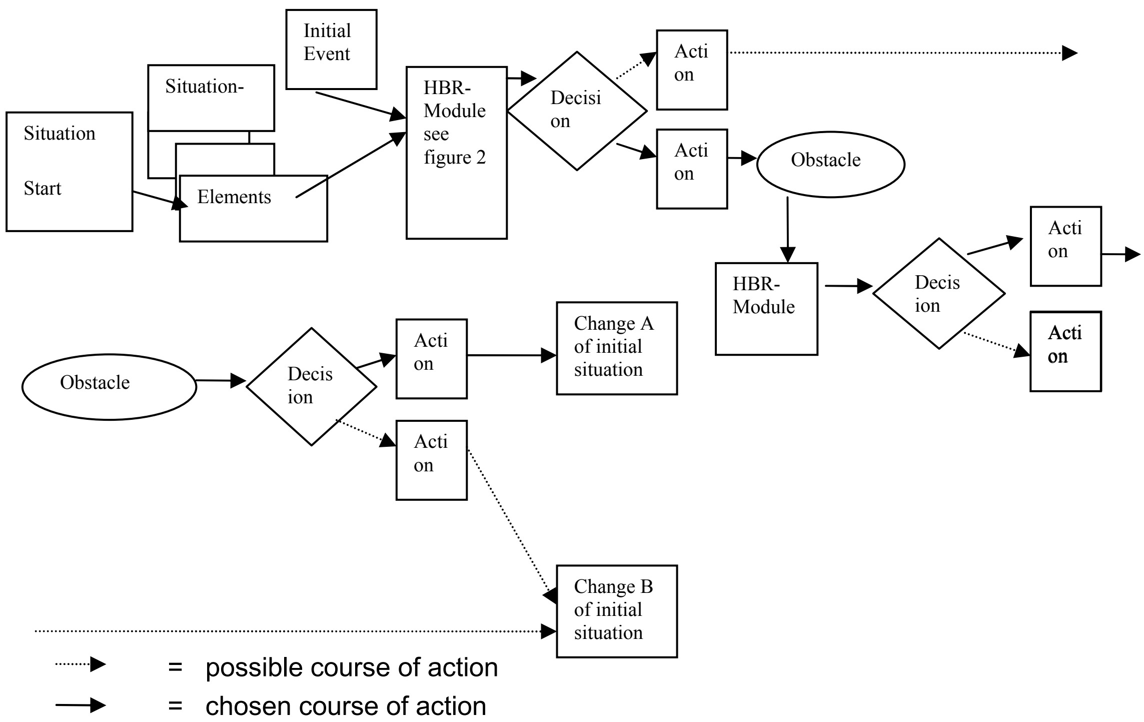

Figure 1: Micro Scenario with HBR Module.

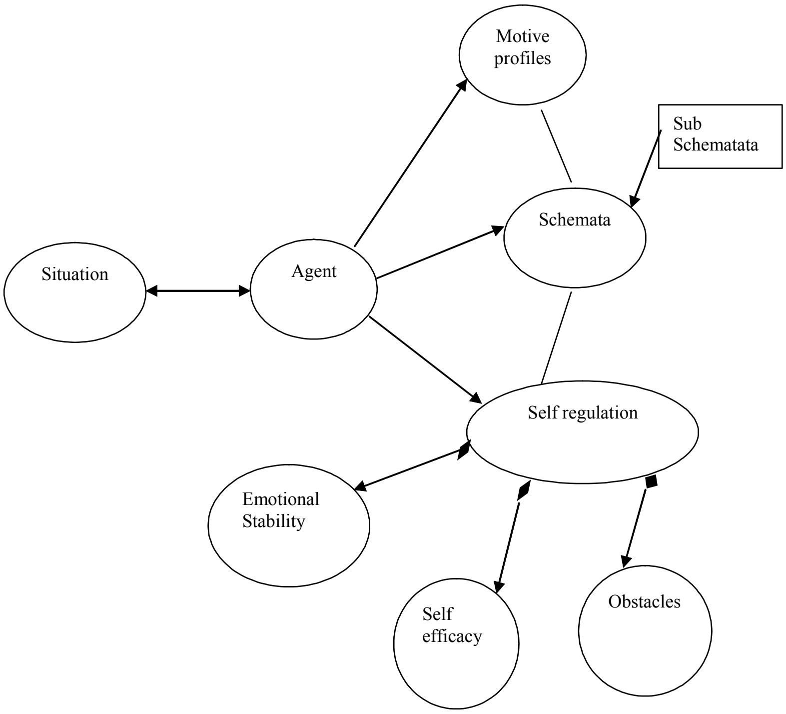

Figure 2: HBR Module (Simplified).

After the principal feasibility of intra-personal HBR has been demonstrated, the upcoming research will address *Organisational Behaviour Representation*, i.e., the question of decision making processes in small groups as well as entire bureaucratic institutions. In addition to the aspect of individual behaviour addressed in the first project, social-psychological (group dynamics) and organisational issues will have to be considered. The research objective is to develop a group-decision making approach addressing decisions in combat as well as in OOTW situations. It is presumed that the main differences lie in the way stressors and social cognition are relevant.

In this context, several fundamental questions need to be investigated, such as:

- Does the military definition of team work and team decision differ from non-military definitions?
- How far supersede military roles and procedures the common way of group interactions?
- What happens when neither of two groups (a military and a non-military) can, in a *common* situation, define a *common* task?
- Do military groups or individuals change their norms and habits when they are confronted with alternative norm-systems, e.g., when they fight together with or against “asymmetric” organisations? How to cope, generally, with norm-conflicts?

3.0 POSTULATES AND ELEMENTS OF A COMPREHENSIVE RESEARCH PLAN

Two years ago, the LTSS on HBR [6] recommended a set of research activities which are still valid but need updating. *Very high* priority was accorded to the following:

- Establish an infrastructure that co-ordinates and facilitates the research on human behaviour modelling (e.g. virtual institute, testbed for demonstrating and studying composability/ interoperability of models).

- Establish a new research effort (e.g. a NATO RTO Specialist Team) on a research plan for team, group and organisational modelling research.
- Establish an additional effort (e.g. a NATO RTO Task Group) to characterise best practice in HBR validation.

LTSS recommendations accorded *high* priority pertain to special problems, most of which are covered by the research goals proposed above, namely:

- adaptive-intelligent coaching
- model of goal-oriented information
- processing (acquisition, evaluation and selection) capabilities and strategies
- automated explanation of behaviour
- reuse of knowledge.

The findings of SAS 017 support the conclusions derived from the author's research in the past two years. Accordingly, there are four practical *postulates* which make Human Behaviour research effective:

1) *Context Centred Modelling*: Don't attempt to "model the human". In other words, do not strive for a general world model of human behaviour in military operations. Some researchers try to do that. However, while such an effort may be of significant value in artificial intelligence research and provide insights useful for applied research, community of applied sciences modelling should always revolve around a well defined context.
2) *Relevance*: Whenever empirical data are required or used, they should be based on well established psychological and sociological theories and capable to explain common sense experience. In other words, data must be empirically and scientifically relevant.
3) *Face Validity*: Do research on processes in a "molar" manner, i.e., in rough granularity and meaningful contexts, not black box input and output analysis and definitely not singular case analysis without general interest. Use typical situations and phenomena and try to define quantifiable processes with a rough predictive value.
4) *The litmus test of behavioural research is its value for simulation*: Analyse the possibilities and limitations of simulation in any given research project and try implement research findings in simulation models and reproduce them in simulation experiments. It should be pointed out, however, that man an academic researcher would not subscribe to this postulate which is indispensable for the applied research community.

If we combine the recommendation of the LTSS on HBR with what we found when analysing the impact of Human Behaviour research, we come to a logical sequence of four research *elements*:

1) Recognise *problem spaces*, where Human Behaviour research can help. A problem space is a multi-dimensional set of inter-related uncertainties. As an example one might consider how to train soldiers of lower rank in coping with decision problems when world wide media coverage is present and the ethical or political mission success depends on his or her action without any chance to ask for superiors' direction. This is a common situation in almost any PSO mission and a fine example of the subjective construction of social reality. A relatively small event may create a big problem; it entails plenty research issues.
2) The concrete need for human science support should be reflected in a *typical scenario* definition per problem-space which exemplifies the need to find solutions. The scenario must contain descriptions of actors, recipients (victims) of actions, alternative courses of action. The actors must be defined in terms, which make it possible to identify the sciences involved.

For example, a decision under media coverage entails at least three scientific challenges: 1) situational and cultural awareness, 2) knowledge about the design and impact of media presentation, 3) decision making under stress. Actors are the particular soldier in question and his comrades, the media "counterpart", a representation of his superiors, a representation of the people and the politics at home. Sciences involved are Cognitive Psychology, Political Science, and Media Impact Research.

3) Compose a team of *scientific experts and military users*[3]. The team should be led by a scientific generalist, who acts as a team moderator and facilitator. The team must become an "expert team" i.e. develop a consolidated knowledge base to solve the pertinent problem-space and push the solution so far as to serve as a basis for Modelling and Simulation. This means that the conceptual work must yield quantifiable constructs and relatively simple production rules. Military research needs robustness and sustainability as any ordinary military operation.

4.0 RESEARCH AREAS FOR HBR

The following problem spaces are proposed for discussion. They are grouped in four research areas distinguished in section 1.4.

Intra-personal behaviour in "asymmetric" situations:

- Research on cultural and socio-economic situations which may lead to *hostile feelings* and eventually to the outbreak of asymmetric hostilities: Why do they hate us and what can we do about it?
- Match or discrepancy of the *mental models* about typical soldier behaviour: Are they really different from us?

Inter-personal behaviour in "asymmetric" situations:

- Asymmetry seen as a *cultural* problem and not just as a difference of combat capabilities: What is *asymmetry*?
- Mental and *behavioural adaptation* to asymmetric opponents: Do we have to become like them?
- *Non-combat interaction strategies* in asymmetric conflicts: How to influence them?

Intra-personal behaviour in OOTW situations:

- Are the *mental requirements* for "warriors" the same as for "peace keepers"? Can we meet both challenges with the same manpower?
- *Qualifications* to change suddenly from war behaviour to OOTW behaviour and vice versa.

Inter-personal behaviour in OOTW situations:

- Social *definition of the situation* in negotiations with non-military or ethnically different organisations.
- Any sort of research into the functioning of Non-Government *Organisations*, in order to improve collaboration.

[3] What is standard in software development, namely the principles of "usability engineering", should also be standard in the scientific model development.

There is much to be done. Most of all, the definition of relevant and important research requires close interaction between the OR/SA and Human Behaviour Sciences community. Early interaction is absolutely essential in studies to support C2 assessment in the new mission environment.

5.0 REFERENCES

[1] Cf. Final Report LTSS on HBR, Chapter 2.

[2] Cf. Rainer H. Kluwe, Stress und Kognition, Interim Report prepared for the German MoD, Hamburg 2001.

[3] St. Reiss and S.M. Havercamp, Toward a Comprehensive Assessment of Fundamental Motivation: Factor Structure of the Reiss Profiles, in: Psychological Assessment, 1998, Vol. 10, No. 2, pp. 97-106.

[4] Cf. for example J. Gerstenmaier and H. Mandl, Wissenserwerb unter konstruktivistischer Perspektive, in: K. Pawlik (Editor), Bericht über den 39. Kongreß der Deutschen Gesellschaft für Psychologie in Hamburg 1994, Göttingen 1995, pp. 362-367.

[5] Cf. e.g. E.H. Witte, Zum Stand der Kleingruppenforschung, in: Pawlik (see fn. 5), pp. 464-469.

[6] RTO Technical Report: TR-047: Human Behaviour Representation, AC/323(SAS-017)TP/25.

To Overcome Challenges in Technology Development in Support of C2 through Social Learning

Swentibold G.C. Stoop
Department of Science and Technology Studies
University of Twente
P.O. Box 217, 7500 AE Enschede
THE NETHERLANDS
(0031) 53 – 4894132

s.g.c.stoop@wmw.utwente.nl

ABSTRACT

Developing technology isn't always easy. Developing information and communication technology in support of C2 appears to be especially difficult. The origin of these difficulties can be traced back to two key challenges, namely: to the alignment of user needs with technical capabilities, and to the timely discovery and understanding of the impact those technologies have on the C2 domain.

This paper is about how we successfully can overcome these challenges. It will show that understanding these two challenges is crucial to achieve success in technology development. It will also show that the resolution of these challenges requires learning. Learning about C2 user-requirements, about capabilities of technology and about how both interact in the C2 user domain.

After decades of research in the field of technology assessment (TA), learning and understanding the interaction of users-needs and technology has proven to be fundamental to successful technology development. Furthermore, its importance is becoming more and more recognized in the field of C2 assessment and development as well, as is shown by Mandeles, Hone and Terry [1996]. Based on insights from constructive technology assessment (CTA) I have developed a model that facilitates learning in technology development. Furthermore, it especially addresses the two key challenges – alignment and timely impact assessment – to the successful development of technology in support of C2.

The NATO code of best practice for C2 assessment (COBP) plays an important role in this model. C2 is still a rather diffuse and complex concept. Yet, if we want to be successful in technology development the articulation of C2 user-needs is crucial. The COBP provides a structure for rigorous discovery and articulation of C2 user-needs. As such it could play an important role in achieving success in developing technology in support of C2.

The model and the COBP do not provide utopia, but they do provide us with a means to overcome the challenges in developing effective technology in support of C2.

***Key Words**: Technology Development, Social Learning, Technology Assessment, Reciprocal Relationships.*

1.0 INTRODUCTION

Developing technology that will effectively support C2 requires learning. It requires learning about user-needs in C2 and about the capability of technology to fulfill those needs. To date that learning them

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has not been as effective as it could have been. This argument could be supported by an awareness that despite the fact that warfare is centuries old, and despite the writings of Sun Tzu and Von Clausewitz, we are still grappling to understand command and control and how technological developments affect it. This makes it difficult to successfully develop technology that fits as closely as possible the requirements of C2 operatives (i.e. commanders and staff). We are learning, but is it enough? And is our learning effective? Because already new technologies like nano technology or genetic technologies have appeared at the horizon and if we are not ready to meet them pitfalls like stove-piping may happen all over again.

The past years have shown that we can develop astonishing, exiting and inspiring new technological artifacts (e.g. Satcom, GPS, GSM, world wide internet, micro RPV's), yet matching technical capabilities effectively with user requirements often remains elusive and difficult to achieve. The results have been C2 systems that work, but do not, or not effectively, fulfill the tasks and requirements set by users (i.e. commanders and staff). In effect these technologies do not effectively support C2 operations. See for example the USAF information support systems during Desert Storm which where not up to the task [Mandeles et all. 1996]. The system worked because the officers quickly learned to bypass the system. Developing effective technology[1] requires achieving successful alignment between (real) user requirements and (real) technical capabilities, and in turn this requires a sound understanding of the user domain, of the technology, and of how these can be matched in the development of effective technology. In other words it requires an understanding of both the *content* and the *process* of technology development.

Linked to the need for alignment of needs and capabilities is the need to understand the impact of a technological artifact on an application domain into which it is introduced. Remember for example the effect of armor and airplane on warfare, or the impact of telegraphy, telephony and radio. Understanding the impact of a technology is necessary if we want to avoid unnecessary and unwanted (negative) consequences, and if we want to take effective preparations, for example to adapt training programs, organization structure or doctrine to the new technology. The US uses an acronym – DOTMLS[2] – that points at these preparations. While the acronym covers useful domains, it does not tell us how a technology will impact on a given application domain; it cannot tell us how to adapt nor what we need adapt to. To discover and understand how and to what we need to adapt we need to understand how technology interacts with its users in a given application domain. More precisely it requires knowledge about the reciprocal relationships between technology, organization and human behavior in the application domain.

In essence what the previous two paragraphs say is that successful technology development depends on *learning* and that this is related to the content and to the process of technology development.

Experience from the field of constructive technology assessment (CTA) states it more strongly and says that learning is crucial for successful development of effective technology [Smit and van Oost 2000]. Its position is that a priori neither a correct solution nor a correct development strategy exists in technology development. However much we know, each development is different, however small, from other developments. For example because of slightly different requirements, or a difference in operational environments. So finding the right solution depends on learning, learning about user-requirements, about technological capabilities, about how to achieve alignment, and about how to discover impacts. Still the question remains how can we learn this, and perhaps more importantly how can we assess if we are learning the right thing?

[1] Effective development is here defined as a process of technology development that results in technology (tanks, airplanes, ICT) that is functional in its application domain (military operations). It implies that capabilities, limitations and impact of that technology are understood. And it assumes that lessons learned from operations and technology development are implemented.

[2] DOTMLS stands for doctrine, organization, training, materiel, leadership, and soldiers [TRADOC 1997].

The answer to this question will be the topic for the remainder of this paper.

2.0 A CTA PERSPECTIVE ON LEARNING

There are several perspectives from which learning can be approached. For example form a psychological or pedagogic perspective, highlighting cognitive and educational aspects of learning respectively. However I will use the perspective of constructive technology assessment (CTA) because I want to focus on learning about the development of effective technology [Smit and van Oost 2000].

Constructive technology assessment [Rip, Misa and Schot 1995] is a paradigm or analytic approach in the field of technology assessment (TA) and science and technology studies (STS) [Jasanof et al.1995]. It differs from other TA paradigms in that it not only develops concepts that improve our understanding of dynamics in technology development, but also develops instruments to improve technology development in practice. This paper presents one such instrument.

An important fundament of CTA is the awareness that success in technology development is neither determined solely by technical nor by sociological factors, but is dependent on (understanding) the reciprocal interplay of technical and sociological factors, commonly referred to as socio-technical aspects of development [Smit and Van Oost 2000]. This can be illustrated by comparing two attempts to develop an information system for the Royal Netherlands Army (RNLA) field artillery, VERDAC and VUIST[3]. During the development of VERDAC[4] miscommunication and mistrust grew over time without any corrective measures being taken. This disrupted the interaction between developers and the RNLA field artillery so much so that technical challenges could not be resolved. After the failure of VERDAC the development of VUIST[5] was started in another attempt to develop a digital wireless CISS for the RNLA field artillery. Initially the same type of social disruption occurred. However, in this instance the RNLA and the developers were able to address the frictions within their interaction. This laid the fundament for improvements in the development process that resulted in the successful development and operational deployment [Wijdemans & Mancke 1995] of VUIST.

Figure (1) represents a graphical representation of VUIST. It depicts the digital network components that links (form right to left) the forward observer to the command and control information system, and through it to the field artillery gun/MRLS batteries [courtesy RNLA, IBT VUIST].

[3] Both cases of technology development have been used to explore and structure the development of an instrument to assess the effect and effectiveness of social learning in technology development.

[4] VERDAC is a Dutch acronym for 'improved digital artillery computer". Its development took place between 1982 and 1987. Though it resulted in a workable system the RNLA decided that it did not match the requirements closely enough and halted the development. The intriguing aspect of this was that VERDAC was the result of a collaborative effort between industry and the RNLA, and had started with a collaborative pre-development study six years before. Yet even so successful alignment didn't seem possible.

[5] VUIST is a Dutch acronym for 'fire support information system'. Its development took place between 1989 and 2000 and is currently fielded by the RNLA Field Artillery.

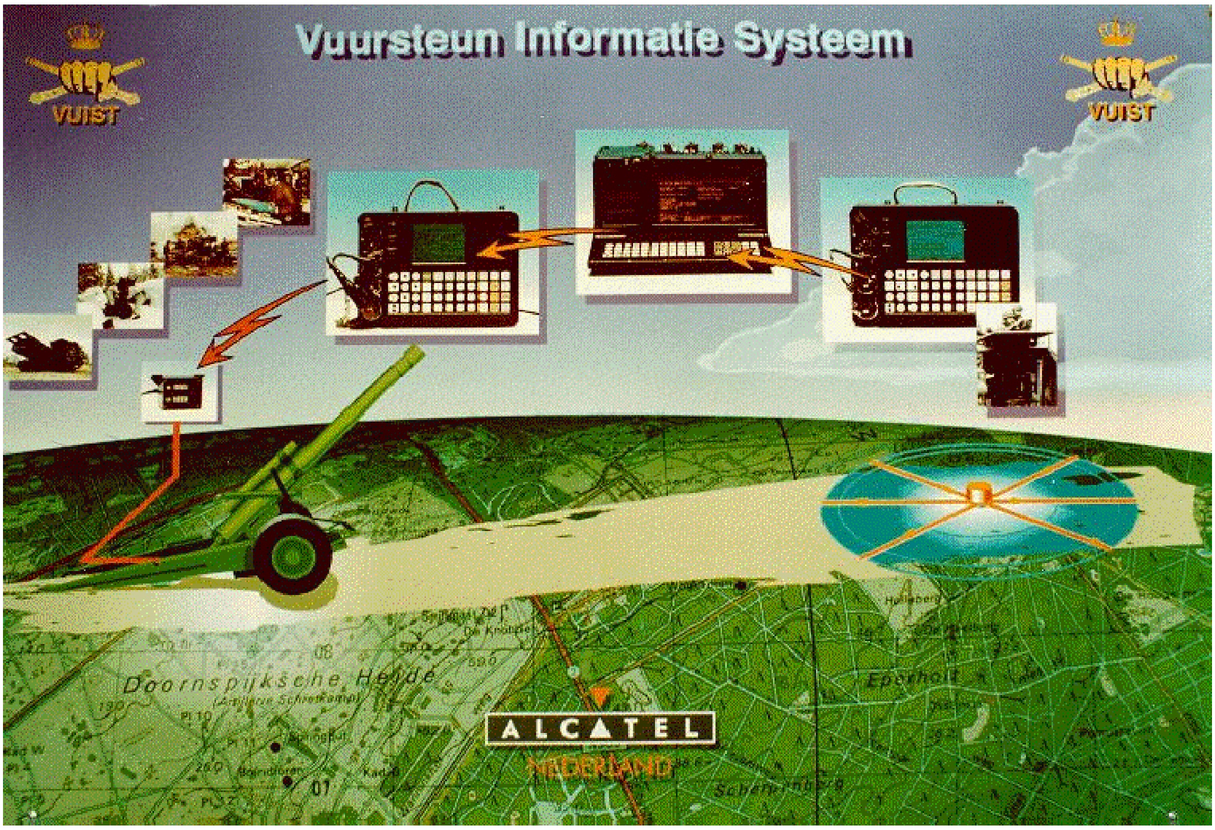

Figure 1: VUIST.

A second fundament is the awareness that successful development means that user requirements and technological capabilities are to be aligned, i.e. that the technology is able to perform effectively those tasks and functions that are required in an operational context. Successful alignment usually requires knowledge of both the user domain and technology domain. Furthermore, successful alignment requires also an understanding of how technology affects the user domain, i.e. an ability to assess if alignment is reached. This is closely coupled to a third fundament that states that it is preferable, often necessary, to discover and identify the consequences of the newly developed technology as early as possible. Most often these impacts are not well understood at the start of the development of new technologies, or how to discover them. Both have to be learned, namely through research or experimentation.

As the complexity of the world around us grows, it becomes more and more unlikely that one person knows it all. Sharing knowledge thus becomes an important part of technology development. It follows that learning in technology development also has to be a social process. It is a special type of learning that takes place in the interaction between players involved in the development of a technology. This is the reason that I refer to this type of learning as *social learning*. In the remainder of this paper I will zoom in on the interaction between intended-users (e.g. commanders and staff officers) and developers of a technology.

3.0 SOCIAL LEARNING: FOUR BUILDING BLOCKS

From a CTA perspective, learning in technology development involves four analytically distinct activities – *articulation*, *reflection*, *feedback* and *embedding of lessons learned* – though in practice the boundaries between them are less distinct and these activities may overlap from time to time.

3.1 Social Learning: Articulation

Articulation is in essence about making ones ideas and thoughts *explicit* and *specific*, so that others may know what you want or know how you perceive a situation to be. Articulation allows others to look at your ideas so that they can learn about them and reflect on them. Only when ideas, or needs for that matter, are made explicit and specific can they be transferred to others, and be discussed.

In technology development clear articulation of user needs (demand articulation) and of technical capabilities (supply articulation) are two very important types of articulation. Without the articulation of user requirements developers do not know how or what they should develop in response to user needs, and without effective knowledge of the operational context their own ideas often do not conform with user expectations. On the other hand users need to have a realistic assessment about the capabilities of a technology. Without it they are most often unable to define realistic requirements that could be fulfilled by technology.

Its importance can also be illustrated by experiences from the development of VUIST. Originally the specification of software requirements did not state in enough detail what the software should do nor how it should be done. (I.e. the demand articulation and technical articulation were not clear, nor specific enough). This made assessment of the alignment between developed software and requirements very difficult. It also led to friction between the RNLA members of the development team and the developers (from Elbit), which in turn almost destroyed their ability to exchange information about their respective knowledge domains (i.e. RNLA field artillery operations & information communication support systems). If they had allowed that situation to continue, alignment would have been impossible to achieve. In practice the participants realized their predicament and resolved the situation by addressing the friction between them in an open en frank manner, closely followed by the articulation of a common strategy for achieving alignment. Part of this strategy was to produce two booklets that became later part of the contract. The first contained the specifications of all the software requirements and improvements, the second contained the specification of how all these requirements would be implemented by the software (technology). These clear articulations facilitated mutual understanding and improved collaboration. In interviews held afterwards, these booklets, and thus articulation, were seen as fundamental to the successful development of VUIST, precisely because they improved communication and mutual understanding.

3.2 Social Learning: Reflection

Reflection in effect is evaluating your activities (which include developing concepts and decision making), or more specifically about the consequences of those activities. Reflecting in this sense is learning about what your activities have achieved, about how you did it, and about if you are content with the results (i.e. the 'what' and the 'how'). Taking time to reflect allows you to evaluate the direction and process of development. Doing this regularly during the development process will not only allow you to monitor the development of technology more closely, but also monitor the process of development – i.e. the 'what' and 'how' in the development process. Doing this regularly enables you to assess if you have to intervene or change early in and during the development itself. Usually that is much better than discovering afterwards that the technology as developed has faults that could have been corrected if timely intervention had taken place.

The development of VUIST can be used to illustrate this point. VUIST was developed in what could be called a 'trial & develop stage' and a 'develop & production stage'[6]*. The 'trial & develop' stage was used to discover whether VUIST was a viable system that could perform the required tasks and functions.*

[6] These two stages did happen, but their name as given in this paper is only meant to identify them in this paper.

Its viability was to be shown in an Operational Test scheme. If this test proved successful VUIST would be further developed and produced for operational use with the RNLA field artillery.

However, the period of the Operational Test was used not only to reflect on the viability of VUIST, but also on the viability of the development process itself. As a result the test procedures in the development stages were changed. In the first stage testing was performed independently by the RNLA and Elbit respectively, though observers could be present. Furthermore there was no common understanding of how this testing should be done, each followed its own rules. This meant that test results (or procedures) of one could not be subjected to rigorous assessment by the other. In practice this meant a loss of effective communication and even miscommunication. If allowed to continue this could easily have led to further misunderstanding or decrease in trust, in effect to a breakdown in development.

In the second stage the tests in development were performed simultaneously by a representative of both the RNLA and Elbit, following a commonly agreed upon scenario. In this procedure each 'error' in the software of VUIST would be the subject of assessment by both representatives, with regard to operational and software development consequences. Both the 'error' and the result of common assessment would be noted in a report. Each day after completion of the test, each 'error' and assessment result was evaluated simultaneously by a senior representative of the RNLA and of Elbit.

Together with the two booklets mentioned in the previous example on articulation, this reflective procedure proved to be effective in acquiring and improving alignment. It also aided in improving mutual understanding and trust.

3.3 Social Learning: Feedback and Embedding of Lessons Learned

Feedback in this context means the transfer of lessons learned in development to others involved in the development process. These lessons might be both about the content (e.g. the software used in VUIST, or experience with VUIST) and about the process (e.g. how the software was developed in VUIST). Furthermore, this feedback is relevant both internal to the development process (e.g. feedback from VUIST-users) and external to the development process (e.g. to other development projects).

Feedback like articulation and reflection is an important part of learning, because without acting on understanding gained no learning in technology development would take place [Shrivastava 1983, Fiol and Lyles 1985]. Just the acquisition of knowledge does not automatically lead to the goal of learning, namely improving the effectiveness of technology development. On the other hand, just taking action or changing procedures doesn't necessarily mean that learning takes place. For example a change in procedure does not necessarily have a positive effect on development, nor is every change accompanied or based on an improved understanding of development [after Tjepkema 1993]. At the same time both articulation and reflection are also an integral part of the feedback process. That is because lessons need to be articulated for others to understand them, while their implication for (other parts of the) development have to be recognized in order to assess how they could be applied.

While feedback internal to the development is often of direct use to that development process, so it will often be applied rather quickly, feedback external to the development process often has no immediate use. It will have to be stored somewhere until it is needed, and be available when needed. This can be quit difficult as it often is stored too well and becomes inaccessible, or it is forgotten, as it had no immediate or clear utility. To avoid a loss of lessons learned they will have to *become embedded in development behavior of individuals and organizations*. This is the fourth building block of social learning in technology development.

An illustration of feedback during development can be found in the activities of the IBT (a Dutch acronym for introduction support team) during the development of VUIST. The IBT was established during the first *stage of development and its task was to facilitate the introduction of this new technological system into the RNLA, and was filled by artillery officers of the RNLA development team. As IBT they started with training the teachers of the fire support education and training center (OTCVUST) and helped them with the building of a curriculum for learning VUIST. Yet they also maintained contact with operational artillery units and helped them to prepare them for the introduction of VUIST. They helped those units with the required reorganization, familiarization, and during field exercises with VUIST. At the same time these officers were members of the RNLA development team directly involved in the development of VUIST. This meant that the members of the IBT could feed user experiences back into the development process, and at the same time feed users an understanding for the functionality's and (im)possibilities of VUIST.*

The efforts of the IBT were much appreciated by the RNLA command and by operational VUIST users, and provided useful insights to the development of VUIST with regard to alignment. However, despite its overall success and utility in development of information systems for C2, the creation of an IBT type team hasn't become embedded in the RNLA (yet). If such a team is established this is done on the basis of individual preferences. Of course any organizational change depends ultimately on individual human behavior, but for the moment there is no organizational structure that supports the use of IBT type teams in the development of C2 information systems. In more general terms this means that there is as yet no infrastructure within the RNLA development community that facilitates and supports feedback processes in the development of information systems. As such it forms an internal barrier against the development of effective technology in support of C2.

This example can be seen as an example of feedback about the content of development.

4.0 A FRAMEWORK FOR ASSESSMENT OF SOCIAL LEARNING IN TECHNOLOGY DEVELOPMENT

So far my answer to the question posed in section one was based on case histories and philosophical discourses in TA. Now these will be translated into an instrument that can be used in the practice of current and future developments of technology; *a framework for social learning in the development of technology*[7].

The purpose of this instrument is the assessment of learning in technology development. In this way it provides an instrument that improves our understanding of, and practice in, how to develop effective technology. In my dissertation I explain how this framework provides insight into the social variables that facilitate or hinder learning in technology development or that facilitate/hinder the embedding of lessons learned. For the purpose of this paper I will focus on the locations in the development process where learning takes place and where an assessment of learning could prove critical for the success of technology development. So far I have identified five locations (or stages) in technology development where technology assessment and thus of social learning is critical to developing effective technology in support of C2. These locations are:

1) the expectations (visions) of technology in a future C2;
2) the specifications of requirements;
3) the choice of an appropriate partner in technology development;
4) the process of technology development;
5) the embedding of lessons learned, and is closely related to organizational learning.

[7] The name of the instrument is provisional, and may change during the writing of my dissertation. For the moment the name contains a set of elements that describe the aim or usefulness of the instrument.

In the remainder of this paper I will focus on the first and fourth locality because they provide a meta-structure or architecture for finding and placing other localities, and because they provide a useful context to describe the role the COBP could have for social learning in the development of C2 technology. This meta-structure is represented in figure (2). In the next paragraphs these locations and their relevance to technology assessment will be described, and will be followed by a discourse on the role of the COBP in this framework for social learning.

4.1 The Assessment of Expectations of Technology in a Future C2

Why is the assessment *of the expectation or vision of technology in a future C2*important? Firstly, through such a vision we create a cognitive framework that guides our thinking, decision making and actions in the development of technology. If this vision is not related to a thoughtful appreciation of future operational requirements and of technological possibilities to fulfill them, then the development of technology may not result in effective support for C2. And secondly, the introduction of technology will have certain consequences for C2 and its environment. These consequences are already implied or present in our expectations of a future C2 and can therefore be explored. If we ignore these consequences until a later stage in development it may be impossible to mediate or negate them in practice.

How can we assess our expectations or visions of technology in a future C2? To assess our expectations we need to bring them in the open and let others (developers, potential or expected users, stakeholders) see and comment on them. In this way we can acquire the most complete understanding on the practicality of our expectations. By bringing it in the open we are forced to be explicit and specific, and therewith provide the material that can and needs to be assessed. From this assessment we can learn if our expectations are practical and if they indeed represent a goal we want to achieve. In effect we need to articulate operational user-requirements, technical capabilities, their alignment and, furthermore, we need to reflect on them and on the possible impacts of technology on C2. To be effective this assessment requires without doubt a sound understanding of the reciprocal relationships between the humans, organizational infrastructure and technology in C2 [Elzen, Ensenrink and Smit 1996; Callon 1992]. This holistic approach is necessary because a change in one element will affect the other elements. In the past many developments of technology have gone awry because the reciprocity of these relations were not taken into account [Mandeles et. al. 1996; Rip et al. 1995], which meant that relevant consequences were left out of the assessment and subsequent development[8]. Of course not seeing them didn’t mean they were not there, they were found in practice, but by then their impact could not be avoided.

Also the assessment of expectations will need to be an iterative process. Earlier we established that we do not know all at the start of a development process, and that we need to learn. This means that as we develop the technology, we will learn more about the process and object of development. These lessons most likely will improve our understanding of the technology in a future C2. Therefore the assessment of expectations of technology in a future C2 will have an iterative nature, if only to check if the development process is still aimed at the desired and intended goal, namely effective support of C2.

Figure (2) represents a graphical representation of the meta-architecture for assessment of social learning in the development of technology.

[8] Experience from many decades of TA have proven that, without the understanding and inclusion of these reciprocal relationships, the assessment or development of technology will fail to deliver effective technology [Smits and Leyten 1991; Callon 1986; Law and Callon 1988; Håkansson 1987] This is because changes in one element of the relationship will affect the other elements. If the reciprocal nature of these relationships is overlooked, unseen but actual consequences will result in a mismatch between human behavior, organizational behavior and technology. In military terms: it will incur friction as an organic part of C2.

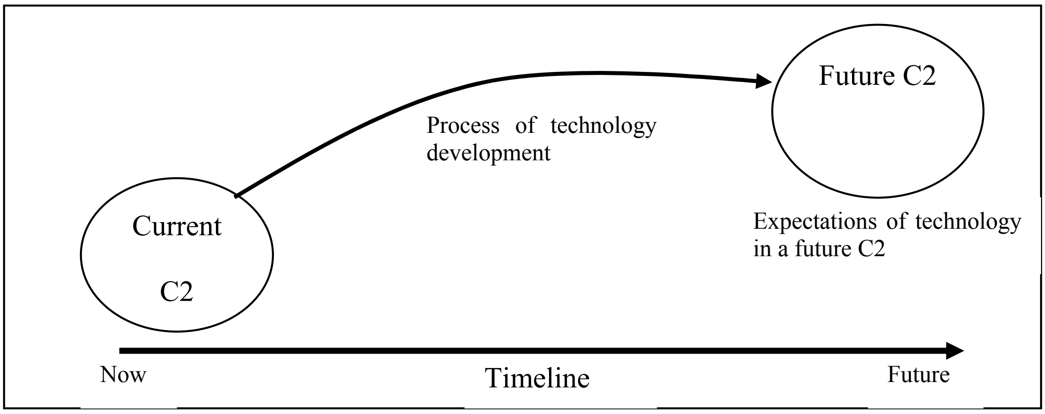

Figure 2: Meta Architecture for Social Learning in Technology Development.

4.2 The Assessment of the Process of Technology Development

The process of technology development, why is assessment of social learning in this location important? It is important because most often we do not know the route to success in advance and therefore need some cues to decide if the route we have taken will lead us to the target we intend to achieve. Social learning in the locality 'expectation of technology in a future C2' provides us with cues about the goal we want to reach and consequences we want to avoid in technology development. Finding cues in the course of technology development is largely depended on interaction patterns between developers, users, principals and other stakeholders. If these patterns facilitate or allow social learning to take place these cues will surface in the practice of social learning. If these patterns hinder or do not allow social learning to take place many cues will remain hidden and success will be depended solely on luck or on some bright individuals going against al odds (and organizational constraints). As the development follows its course and learning takes place, changes in user-requirement, technological capabilities, technological impacts or development methods may require a re-assessment of the aiming point or may require a re-assessment of the development path followed so far. This may require backing up a little and choosing a different route.

What does this mean in practice? It means that we need to assess if the development strategy is in line with the intended aim as articulated in the (assessed) vision of technology in a future C2. This involves amongst others an assessment of utility of the design-tools and procedures used to develop the technology, of the methods used to achieve alignment between user-requirements and technical capabilities; and of the methods used to discover impacts of our decisions made in technology development. Of course articulation of user requirement and technical capabilities remain central issues. Implicitly this means that articulation is not a one-off, static activity, but rather an iterative dynamic activity. Good development practice will try to facilitate this iterative process.

5.0 THE ROLE OF THE COBP IN THE ASSESSMENT FRAMEWORK FOR SOCIAL LEARNING IN TECHNOLOGY DEVELOPMENT

How does the COBP fit into all of this? The primary role of the COBP in the framework for social learning are located in the assessment of expected future C2, and is related to the fundaments for achieving effective technology in C2, namely alignment and impact assessment. It does however also have some secondary roles that merit attention. These secondary roles are related to the provision of rigor and iteration in assessment, and to the embedding of lessons learned.

5.1 The Primary Role of the COBP in Social Learning

The assessment of our expectations of technology in a future C2 is crucial to the development of effective technology. However, it is not often that it is performed well. If the NATO code of best practice for C2 assessment would be used in the assessment of our expectations of technology in a future C2, it could provide a structure that almost forces one to perform the assessment well (i.e. well structured, rigorously and in iterations). More specifically it could be useful in the articulation of user requirements and impact assessment.

Firstly, its usefulness in the articulation of user-requirements. Despite our advances in C2 research and development, C2 to a great extent remains a diffuse knowledge domain. This makes the articulation of C2, i.e. translating our understanding of C2 into C2-requirements, more difficult than articulation of requirements already is. Yet without it we cannot develop effective technology to support C2. The COBP could help us to overcome this dilemma, by using it as a method to find those issues in the C2 domain that need to be articulated. Secondly, when assessing the impact of technology in C2 we are interested in how it affects C2 behavior and its environment. In order to assess the impact of technology on C2 we need to understand the dynamics of C2, without it assessment will be impossible. At the moment our understanding of C2 dynamics does not present a comprehensive whole, but rather consists of a whole range of dispersed knowledge, situated in a variety of individuals, institutions and disciplines. The COBP could provide a guide that facilitates a convergence of C2 knowledge that will enable an effective impact assessment of technology in the C2 domain.

Why could the COBP be used in this manner? Well the COBP pays particular attention to problem structuring and forces the analyst (who might also be a user or a developer etc.) to become very specific in the issues that are relevant to a certain problem. It states for example that "the problem is not formulated until the assessment team has <u>specified each aspect of the problem</u>" [COBP 2002] (underlined by Swentibold Stoop). Also the COBP explicitly uses an iterative approach C2 assessment. This allows for the inclusion of new knowledge and experience in the course of assessment. In this way it stimulates learning and facilitates more detailed specification of C2 requirements. Furthermore it guides developers, technology users and others using the COBP to the discovery of measures to assess the impact of technology on the performance of C2. For instance it provides guidelines for using scenarios to assess the impact of technology in a future C2 in a variety of operational environments. Though as yet, the COBP is more oriented on the external effects of C2 change and less suited to the discovery of impact on the internal functioning of command post.

5.2 The Secondary Roles of the COBP in Social Learning

Here I want to briefly mention two issues – rigor and embedding of lessons. The iterative assessment structure of the COBP enforces, or at least facilitates a rigorous approach to assessment, ensuring comprehensiveness. Yet it does more, through its chapter on risk and uncertainty it facilitates reflection on the tools and methods of assessment that are used in the assessment of C2. In this way it facilitates discovery and learning of appropriateness of the process and procedures followed. This may also facilitate, and hopefully stimulate, reflection on solutions and solutions strategies used in technology development.

The COBP is based on lessons learned in the practice of C2 assessment, so it represents an example of embedding lessons learned. As it is aimed at analysts involved in C2 research and development in NATO and beyond, this example could reach far and wide in the C2 R&D community. The intention to revise it iteratively also furthers the aim of embedding, as does the presentation of iterations as method of best practice in C2 assessment. If this aim of the COBP is more widely understood and implemented, for example in the framework for social learning in technology development, it could facilitate the embedding of development lessons in individuals, institutions and disciplines.

5.3 Some Reservations about the Role of the COBP in Social Learning

Finally, I want to present some reservations about the utility of the COBP in the framework for social learning in technology development. The COBP is sometimes too much focused on specific variables and quantitative analysis. Effective articulation of C2 issues may require the inclusion of more qualitative and holistic assessment of C2, especially with regard to the reciprocal relationships between "*human behavior–organizational behaviour – technology*" in C2[9]. The need to understand these reciprocal relationships becomes more and more recognized in the C2 research and development community. Therefore I expect that we will see improvements in this area in future revisions of the COBP. However, for the moment other assessment tools like CTA [Smit and van Oost 1999] or the perspective of boundary work [Gieryn 1999; Gunston 2001] offer more fruitful methods to cover the assessment of these relationships.

The COBP does stress that the assessment team needs access to matter experts, and in its introduction recognizes the need for a comprehensive assessment. But probably because it is still mostly oriented towards operational research (OR) analysts, it as yet does not provide measures to make the required interdisciplinary teamwork. Effective interaction between different subject matter experts requires specific skills and approaches that require them to step outside their respective cognitive frames to develop a common cognitive frame. This could be achieved by mediators experienced in developing and using such a common frame or by educating and training respective experts. To be fair, the COBP mentions this need, and overall the COBP is a great improvement. Yet from a social learning perspective, the relevance of this issue merits a more specific address than it currently has in the COBP.

6.0 SUMMARY

This paper was based on the preliminary findings from ongoing dissertation research on developing effective technology in support of C2. In this dissertation the thesis is that social learning is crucial to the development of effective technology. It is further recognized that learning does take place but poses that this isn't translated into a general understanding of dynamics of technology development. Consequently technology development too often results in less than effective technology in C2. This may seem outrages, but the examples of VERDAC and VUIST prove otherwise. Furthermore they showed that the concept of social learning provide an explanation for the failure and success of VERDAC and VUIST respectively.

Social learning involves four activities, namely articulation, reflection; feedback and the embedding of lessons learned. These activities take place in the interaction between actors (expected users, developers, and other stakeholders) in development of technology. The social variables that affect the occurrence of social learning in this interaction are the current topic of my dissertation research.

To identify localities in technology development were social learning is essential I have developed a "framework for social learning in technology development. So far I have identified five localities where this is the case. In this paper I have described two of them, namely the 'expectations of technology in a future C2'; and the 'process of development'. Their relevance is twofold. Firstly, together they provide architecture for finding and placing other localities. Secondly, the first provides a frame of reference for decision making in the development of technology and the second a frame of reference for assessing whether the development is still on course.

[9] For completeness I should note that I myself am a member of the sas-026 panel and co-author of Chapter 6 "Human Organization Factors" in the (revised) COBP. Revising the COBP was a collaborative effort and achieved many improvements over the original COBP. Even in the area of human and organizational issues in C2. Yet on some issues in this area the work hasn't yet finished and will provide a challenge for future work on the COBP.

The role of the COBP in technology development is located in assessment of our expectations of technology in future C2. Its primary role is finding C2 issues that need to be articulated, and to support the impact assessment of technology on C2. Yet some secondary roles can also be identified, namely its support for rigor, iterations and embedding of lessons learned. Still, there are also some reasons for caution. The COBP as yet, is not well suited to assess the internal workings of C2. Also, currently it doesn't provide enough guidance to the application of multi-disciplinary assessment teams that are required to assess the complex range of C2 issues.

Overall, the COBP and CTA provide complementary tools and insights that are relevant to the development of effective C2 technology. In this paper I have stated the case from the perspective of CTA. However from the COBP perspective CTA could play an important role in the technology assessment and the assessment of the reciprocal relation with human and organizational issues, both in current and in future C2 problems.

And last but not least, both the COBP and CTA do not provide Utopia. They do provide effective means to improve our understanding of C2 and technology development respectively. Together they provide the tools to overcome the challenges to effective technology development in C2.

7.0 REFERENCES

Callon, M. (1986), "The Sociology of an Actor-Network: The case of the Electric Vehicle", In: Callon, M., Law J. and Rip, A (1986), "Mapping the dynamics of science and technology", The MacMillan Press Ltd.: London.

Callon, M. (1992), "The Dynamics of Techno-Economic Networks", In: R. Coombs et al (1992), "Technological change and company strategies", Academic Press: London.

COBP (provisional) 2002, "The NATO Code of Best Practice for Command and Control Assessment".

Elzen B., Ensenrink, B. and Smit, W.A, (1996), "Socio-Technical Networks: How a technology studies approach may help to solve problems related to technical change", In: *Social Studies of Science, vol 26*, pp. 95-141.

Gieryn, T. (1999), "Cultural Boundaries of Science: Credibility on the Line", University of Chicago Press: Chicago.

Guston, D.H. (2001), "Boundary Organisations in Environmental Policy and Science: An Introduction. In: Science, Technology & Human Values", Journal of the Society for Social Studies of Science, volume 26, number 4, Autumn 2001, Sage Publications.

Law, J., and Callon, M. (1988), "Engineering and Sociology in a Military Aircraft Project: A Network analysis of Technological Change", In: *Social problems, vol 35, nr 3*.

Håkansson, H. (ed.) (1987), "Industrial Technological Development. A Network Approach", Routledge: London.

Fiol, C.M. and Lyles, M.A. (1985), "Organizational learning", In: *Academy of Management Review,* jrg 10, NR 4, pp. 803-813.

Jasanof, S., Markle, G.E., Petersen, J.C. and Pinch, T. (eds.) (1995), "Handbook of Technology Studies", Sage: Thousands Oaks, CA.

Mandeles, M.D., Hone, T.C. and Terry, S.S. (1996), "Managing Command and Control in the Persian Gulf War", Preager: West Connecticut, London.

Rip, A., Misa, J.T. and Schot, J. (1995), "Managing Technology In Society. The approach of Constructive Technology Assessment", Printer Publishers: New York and London.

Shrivastava, P. (1983), "A typology of organizational learning systems", In: *Journal of management studies*, NR 2, pp. 7-28.

Smit, W.A., and van Oost, C.J. (1999), "De Wederzijdse Beinvloeding van Technologie en Maatschappij : een Technology Assessment-benadering", Cotinho: Bussum.

Smits, R. and Leyten, J. (1991), "Technologie Assessment: Waakhond of Speurhond? Naar een integraal technologiebeleid", Dissertation at the University of Twente, Kerckebos b.v.: Zeist.

Tjekema, S (1993), "Profiel van de Leerende Organisatie", Centrale reproductie-afdeling Univeristeit Twente.

TRADOC (1997), In: URL http://www.fas.org/irp/agency/army/tradoc/.

Wijdemans, P.C.J. and Mencke, J.B. (1995), VUIST-1, Vuursteun Informatie Systeem, Proefsysteem, Borrias Planodruk: Zwolle.

8.0 LIST OF ACRONYMS

C2	Command and Control
COBP	Code Of Best Practice (NATO code of best practice for C2 assessment)
CTA	Constructive Technology Assessment
DOTMLS	Doctrine, Organization, Training, Materiel, Leaderships, Soldiers
ICT	Information and Communication Technologies
NATO	North Atlantic Treaty Organization
OR	Operational Research
RNLA	Royal Netherlands Army
STS	Science and Technology Studies
TA	Technology Assessment
VUIST	Fire support information system ("Vuursteun informatie systeem")
VERDAC	Improved Digital Artillery Computers ("Verbeterde digitale artillerie computer")

AUTHOR BIOGRAPHY

Swentibold G.C. Stoop is a Ph.D. student at the department of Science and Technology Studies at the University of Twente. Before he started his work at the University of Twente, he worked two years in support of ISDN networks at KPN, and in a separate effort developed the wargame "Teamwork" for the RNLA.

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Agent Based Evidence Marshaling: Discovery-Based Enhancement Tools for C2 Systems

Carl W. Hunt
Lieutenant Colonel, US Army
US Army Criminal Investigation Command
8652 Morning Star Ct.
Springfield, VA 22153
USA
[1] 703-805-3528

huntc@belvoir.army.mil

ABSTRACT

Developers introduce new technologies at rates that defy prediction. This phenomenon applies to both new and existing sources of information, as well. As the recent attacks on America demonstrate, the result is an ever-increasing glut of information competing for our attention in ways that are unprecedented in history, potentially bringing even the most sophisticated command and control (C2) tools and practices to their knees. Conventional methods for organizing and focusing information for C2 purposes do support the current situation; for example, the scenario is one of the major methods in view within the NATO Guide to Best Practice in C2 Assessment for this purpose. Scenarios can be of immense value in evaluating information and relationships of that information to various C2-related environmental constraints. The methods by which we construct and interact with scenarios must be subject to constant review, however. This paper offers novel methods for scenario development and interaction, based on modeling techniques that embrace multidisciplinary thinking – the agent-based model. In fact, a meaningful method for better understanding how life and the massive information it routinely processes may actually be manifested in straight-forward uses of agent-based models. This paper describes an agent-based model called the Agent Based Evidence Marshaling (ABEM) model, and discusses ways to enhance scenarios that support Best Practices in Command and Control. ABEM brings to convergence centuries-old studies of semiotics and inference with recently introduced models for discovery and insight within an agent-based modeling environment – scenario development is one of ABEM's primary objectives.

Key Words*: Modeling and Simulation, Scenario Generation and Testing, Decision Support.*

1.0 INTRODUCTION

Developers introduce new technologies at rates that defy prediction. This phenomenon applies to both new and existing sources of information, as well. As the recent attacks on America demonstrate, the result is an ever-increasing glut of information and technologies competing for our attention in ways that are unprecedented in history, potentially bringing even the most sophisticated command and control (C2) tools and practices to their knees. Conventional methods for marshaling and visualizing information for C2 purposes are of modest help to the current situation; for example, the scenario is one of the major methods

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in view within the *NATO Code of Best Practice in C2 Assessment* (COBP) for this purpose. Scenarios can be of immense value in evaluating information and relationships of that information to various C2-related environmental constraints. The methods by which we construct and interact with scenarios must be subject to constant review, however. This paper offers novel methods for scenario development and interaction, based on modeling techniques that embrace multidisciplinary thinking – the agent-based model. Although labelled *agent-oriented modeling* in the COPB chapter on Methods and Tools, the descriptions of both are sufficiently similar to use the terms interchangeably. For this paper, I employ the term agent-based modeling.

What decision-makers faced with rapid information flux now need is a data-to-decision, scenario-enhanced continuum that offers insights at any point in the cycle in order to increase decision support. Interestingly, increasing sophistication in decision support systems may not even be needed, as life itself substantiates. A meaningful method for better understanding how life and the massive information it routinely processes may actually be manifested in straight-forward uses of agent-based models. Such models can provide data-to-decision enhancement through discovery. This paper describes an agent-based model called Agent Based Evidence Marshaling (ABEM) that has shown promise in enhancing the process of discovery through scenario generation and interaction.

ABEM brings to convergence centuries-old studies of semiotics and inference with recently introduced models for discovery and insight within an agent-based modeling environment – scenario development has always been one of ABEM's primary objectives. The ABEM environment focuses investigators, analysts and decision-makers toward better inquiry about the contents of their knowledge bases. As an enhancement to C2, ABEM provides a discovery-based setting for information to self-organize into meaningful representations of knowledge that potentially expose gaps, sometimes referred to as "what we don't know," or "unknown unknowns" as the NATO COBP labels it. From these visual depictions may emerge new line of inquiry and testable hypotheses, embedded in scenario form, that assist in the search process for evidence or information to fill in the gaps and produce more sophisticated scenarios about the evidence under examination.

This paper is presented into three parts. The first part presents an overview of discovery, semiotics and agent-based modeling, including its root dynamics as a component of Complexity Theory. The second part of this paper introduces the Agent Based Evidence Marshaling model and its potential impact as a C2 discovery-enhancing tool for improving scenario development and interaction. Finally, this paper describes likely extensions of the model into more generalized categories of command and control, interweaving semiotics and complexity theory. Principal findings focus on the enrichment of the processes of nature and agent-based modeling, as enhanced by the process of discovery, to novel methods for C2 planning to increase situational awareness and force protection.

2.0 SEMIOTICS, DISCOVERY AND AGENT-BASED MODELING: ENABLERS FOR EFFECTIVE C2

2.1 Revolutionary or Evolutionary?

Imagine what historians of 100 years from now may think about what many, including the 2002 NATO Code for Best Practice for Command and Control Assessment, claim is a "Revolution in Military Affairs." These historians will weigh the modifications we made in fighting our nations' wars in terms of all contemporary technological advances. As an example, some military historians of today consider that another "revolution" we call information age warfare emerged with the introduction of the technology of the telegraph. In the next 100 years, information-based technologies will populate our world in ways in which we may not even be aware, and will increasingly lead to an understanding of just how close humanity and society (and warfare) parallel the development of life over the past few billion years. Biological information has been at the root of this unpredictable growth, which has actually been much more evolutionary than revolutionary. Our current perspective may suggest revolution, but in the long view, we are living in evolutionary times. Future historians may chuckle that we considered ourselves revolutionaries in warfare. Humility and inspiration from nature are key watchwords for us here.

Whether we label it revolution or evolution, the matter is still of great importance. Let us consider best practices in command and control as products of evolution for the purposes of this paper, however, in order to better understand the model that life provides to the novel information technologies that will lead us toward "best practices." Geopolitics aside, the challenges to understanding how to best leverage new information-based technologies and develop a conceptual dimension for deploying them will be discovered in models of life, eventually following the principles of emergence and self-organization. We may soon lose the ability to optimally engineer simple solutions for complex problems, and rather seek to grow them, in self-organizing fashion, as products of evolutionary improvement. These solutions could significantly enhance best practices for command and control. For eons, life has proven it works well enough through evolutionary processes.

The role of information management and technology, particularly as it has been assisted by artificial intelligence, ranks as one of the prime applications of technological development today. The ability to perform automated complex calculations and to store results for later use has been an objective since even before Charles Babbage's analytical engine of the early 1800's. Information technology and management are of critical importance to almost every facet of modern life. It has only been since World War II and the requirements of major military projects such as the Manhattan Project that we've seen significant breakthroughs in information technology, however. The study of computer science as a major discipline has empowered this growth. At the beginning of the 21st Century, with increased focus on the disciplines of biology, artificial intelligence and complex adaptive systems, we see what may be the beginnings of yet another period of breakthrough in information technology. In the extended view of history, however, these achievements still remain more evolution than revolution.

2.1.1 Complexity Theory and Semiotics

Information technology has also been an empowering mechanism for Complexity Theory and its older cousin, semiotics. Complexity Theory is only now finding its own definitions. In his popularization of the budding discipline ten years ago, Waldrop related that complexity science is "so new and so wide-ranging that nobody knows quite how to define it, or even where its boundaries lie" [Waldrop, 1992]. There are however signature disciplines that compose the sciences and theory of complexity that prepare us for how to think about the relationships of living entities and information management, through the interdisciplinary threads that compose this theory. I suspect that most complexity theorists would agree that complexity deals with the study of complex adaptive systems that embody the interactions of independent agents, in self-organizing schema, that produce emergent phenomena that typically cannot be predicted from observations of the lower level entities that compose the interactions. If we find clues from nature, the ideas resulting in the development of the concepts of semiotics, we have powerful heuristics to shape our understanding.

The major disciplines that compose complexity theory include biology, physics, economics, psychology, mathematics and the computer sciences. There are also other disciplines that have been applied to the study of complex adaptive systems. The real focus is on the idea that complexity embraces a variety of studies that have at their root the quest to understand how organic (and even inorganic) entities come to exist and behave in the manner in which they do. In that way, Complexity Theory displays keen similarities to semiotics, the study of signs and systems that rely on signs, such as nature herself. The better known study of semantics is in fact an examination of linguistic signs such as words, searching for connections to ideas and thoughts through meaning. Semiotics also looks for meaning in the broader context of nature.

The study of complexity is the study of life's entities and the environment in which life exists, and how these entities interact with each other to produce the behaviors that we can ultimately observe. Complexity studies have borrowed important concepts from each other, often in metaphorical terms, in order to explain how things interact, work and prosper, including information. In fact, Charles S. Peirce and Richard Dawkins argued that ideas can be alive and propagated through human life. Dawkins called these living ideas *memes* [Dawkins, 1989], while Peirce characterized them as "substantial things" [Buchler, 1955, 340]. This concept and the study of memetics that accompanies it also manifest in the thinking behind complex adaptive behavior [Blackmore, 1999].

2.1.2 Peirce, Abduction and Complexity Theory

Peirce's thoughts about the inference model he called abduction and the notion of living ideas are fundamental to the concept of emergence, as discussed throughout this paper. In fact, Peirce's descriptions suggest that he considered ideas to have a living force or "energy" and that ideas may even be capable of interacting with other ideas and produce their own force. He spoke of how "all mind is directly or indirectly connected to all matter" [Buchler, 353], and how there is such a thing as "a living idea" [349]. In coming very close to describing emergence, Peirce writes, "A finite interval of time generally contains an innumerable series of feelings; and when these feelings become welded together in association, the result is a general idea" [346]. Here Peirce describes living feelings, interacting with other living feelings, to produce what can only be characterized as living ideas. It is this essentially undirected emergence that can improve the way we "live" and interact with our information in the world of command and control. Now, when we tie the ideas of emergence to the concept of discovery, we begin to see the power that nature may truly wield in information technology. We must consider these notions in the light of "best practices" in command and control.

If ideas are alive, intellectual creativity and discovery through abduction is a life-producing process. Can we borrow from nature meaningful ways to enhance information technology in a method that stimulates discovery and our production of creative ideas – ideas that we can visualize in the building of novel agent-based scenarios? Can we "artificially" stimulate the creation of ideas in silicon that boost our human creativity, even borrowing from the apparent successful model of "living" memes so that we might discover what we didn't know or was obscured by masses of data before? If this is indeed possible, then biology and the other complexity sciences provide models for how we may emulate natural creativity. These models are manifested in agent-based modeling, a significant mechanism for discovery that has grown out from the disciplines embodied in complexity theory [Axelrod, 1997, 3-4]. Agent-based models can provide powerful reflections of life-like properties.

Harvard biologist Edward O. Wilson notes that multi-disciplined approaches to understanding our world are hardly new. Wilson writes of an "Ionian Enchantment," a belief in the unity of sciences in the times of Thales of Miletus of sixth century B.C. Greece, and an inspiration to Aristotle. Wilson recounts how the Age of the Enlightenment, a time of exploring the intersections of scientific disciplines, was corrupted by the politics and religiosity that preceded the French Revolution [Wilson, 1998, 4-15]. Basically, until the separation of the sciences into various disciplines, a likely by-product of the industrial revolution, all the sciences lumped together were known as "natural philosophy." Even Francis Bacon, representative of history's greatest natural philosophers, speaks of manifest properties arising out of inner structures in his discussions of "latent schematisms" of matter [Bacon, pub. 1994]. Complexity theorists talk of these "manifest properties" as the results of *self-organization*.

Self-organization represents significant importance for complexity-based modeling and simulation. Per Bak notes that self-organized criticality is the basic engine for producing complexity in the real world. Self-organized criticality can occur when a complex system discovers an area within its environment that facilitates evolution [Bak, 1996]. Some complexity theorists call this area the *edge of chaos,* a site for innovation or adaptation. This is an area far enough removed from frozen order and not too close to the inscrutability of chaos, hence the notion of the edge of chaos. Perhaps we find this edge of chaos in the "sweet spot" of *emergence*, as shown in a notional discovery and decision-making environment in figure 1, below.

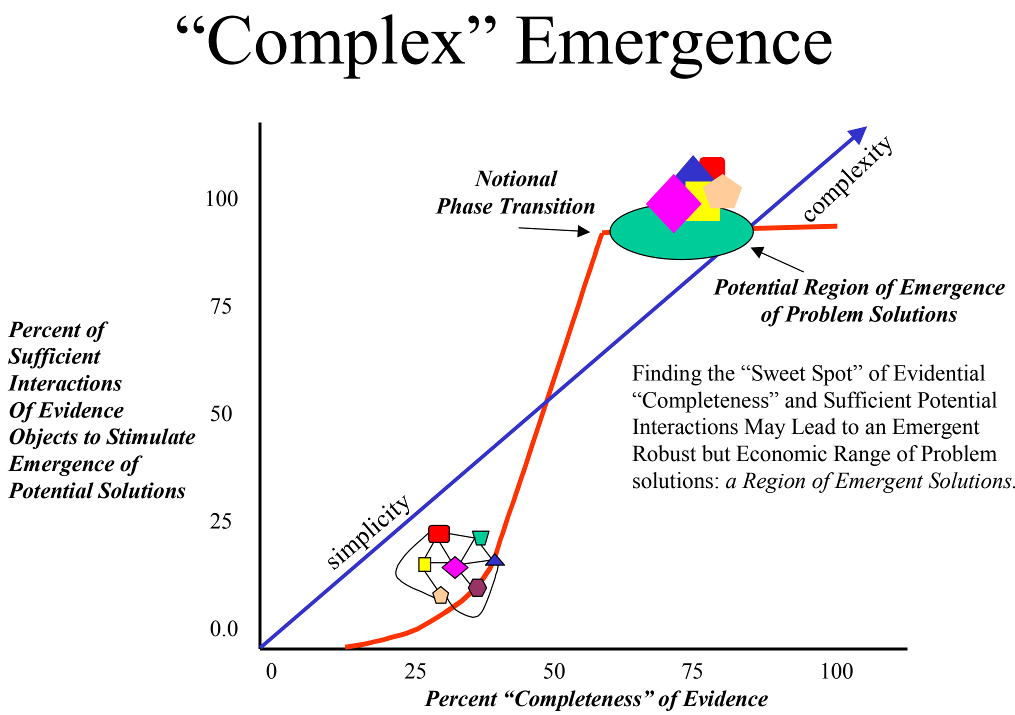

Figure 1: "Complex Emergence".

This drawing depicts how a decision-maker may map a region of possible solutions that emerge through rich interactions of evidence, once a sufficient amount of evidence has been obtained. The thesis of this drawing is that once there exists a sufficiently "complete" set of evidence observations or data points, and these observations have been empowered to interact in an agent-based modeling environment for a "sufficient" amount of time, there will occur a phase transition that produces an environment for the emergence of a region of possible problem solutions. As occurrence of interactions of evidence proceed up the slope to this region (e.g., increasing), solutions progress from simple to complex, with the more complex solutions offering robustness in potential alternative solutions that encompass relevant critical items of evidence. An economy of solutions emerges that provides the decision-maker with new directions for query and understanding.

In the instance depicted above and indeed in general, "simple" solutions are preferred over "complex" solutions, but simplicity often obscures the power of interaction and interrelationship. Agent-based modeling such as the Agent Based Evidence Marshaling model discussed below is a candidate tool to parse complex interactions into simple visualizations where the detail is captured and available for study, if needed.

2.2 Evidence Organization: A Tool for Discovery in Complex Systems

This section begins with an examination of the work of David Schum and others as they have built upon many years of thinking about the organization of evidence and information to support better inquiry during fact investigation and more effective presentation of evidence before a court of law, a very high-level decision-making authority. At this point, it is important to consider evidence as a formalized description of information for decision-support in Command and Control as well as in criminal investigations and intelligence analysis. I briefly discuss an early prototype system called *MarshalPlan*, a computer-assisted but manual system for evidence marshaling that has received significant interest over the years of its development, including National Science Foundation support. Much of their writing on evidence marshaling and *MarshalPlan* points out the shortcomings of conventional methods of information organization, including Data Mining and Knowledge Discovery in Databases.

2.2.1 Evidence Marshaling and Discovery: The Inspiration and Backbone of Agent Based Evidence Marshaling

This paper posits one overriding theme: imaginative discovery of information in support of generating hypotheses and enhancing the process of inquiry in building and interacting with scenarios in Command and Control systems. David Schum and Peter Tiller's work on evidence marshaling provides a theoretical framework for expressing the most important observation and building block that permeates this theme. As Schum recently put it "how we marshal our thoughts and evidence has an important bearing on the discovery process itself as well as on the process of drawing conclusions from what we have generated or discovered" [Schum, 1999, 402]. Evidence marshaling is all about organizing masses of evidence to support imaginative discovery of "hypotheses, evidence and arguments" as Schum describes it, leading to more imaginative scenario building.

Evidence marshaling is an attempt to inscribe a bit of formality within the discovery process. In overview, it is quite simply a mechanism to support evidence organization and reasoning, but in concept it does so much more. Evidence marshaling places imaginative fact investigators "inside" their body of evidence, able to manipulate it in ways that allow the generation of new ideas, new evidence and new scenarios. Evidence marshaling allows the investigator to perceive more readily possible interactions among evidence items.

Schum points out that the generation of evidence is an important part of evidence marshaling, and that imaginative inquiry and scenario generation, as part of evidence marshaling, greatly facilitates this activity. I have yet to meet an investigator of any type who would reject assistance in generating evidence to support a claim or hypothesis. In fact, successful investigators will even welcome evidence to refute hypotheses, ala Francis Bacon. A major objective of Schum and Tillers, has been the following: to formalize the organization of evidence to aid the investigator in asking the "right questions" that could uncover critical links to evidence that either should exist or does exist behind the veil of complexity.

Even manual forms of evidence organization can be of assistance in this goal, as Schum and Kadane have shown in their analyses of complex criminal investigations and trial proceedings [Schum and Kadane, 1996]. My experience as a criminal investigator and my analysis of interviews with other investigators bears this out. Methods ranging from investigative notebooks (both manual and automated) to carrying around evidential observations on 3x5 cards exist throughout the legal, intelligence and scientific communities. These methods also reflect evidence marshaling techniques.

In 1987, Schum and Peter Tillers received support from the National Science Foundation to formalize discovery-related issues in fact investigation. They called the model formalized during this study

MarshalPlan. The mechanisms embodied in *MarshalPlan* can be integrated with graphing conventions first proposed in the 1930's by Henry Wigmore, arguably America's foremost scholar of evidence. Wigmore's Inference Networks are graph-based constructions of complex arguments based on evidence [Anderson and Twining, 1991]. He proposed that for an investigator or lawyer "to get the 'big picture,' we do need a picture showing how…statements or propositions fit together." In Schum's adaptation of Wigmore's work, the graph is composed of nodes and arcs. "Nodes consist of certain statements or propositions, and arcs specify their probabilistic linkages" [Schum, 1994, 162]. Schum's and Tiller's efforts have generated important discussions about several key points concerning evidential organization and reasoning.

As Schum notes, the way in which we organize our evidence greatly influences the questions we ask and the hypotheses we form about our evidence. "Thoughts and evidence organized or juxtaposed in one way can lead to significant insights that do not flash before us when these same thoughts and evidence are organized in other ways," notes Schum [1999, 402].[1] Schum and Tillers developed the idea of a metaphorical magnet to act as an attractor for organizing evidence in various ways. Within the *MarshalPlan* system a temporal magnet is one of the most commonly used and easy to visualize. As Schum indicates in his description of temporal magnets, "many of the trifles or details we gather, whether testimonial or tangible, are time-stamped [1999, 441]." The organization of evidence through event chronologies is an example of applying a temporal magnet. Temporal perspectives, particularly when combined within the space-time vectors that ABEM evidence object-agents employ, are of great important in the ABEM model.

Wigmore formalized the importance of using chronology in breaking out evidence in three ways within his network structure. Wigmore prescribed the use of prospectant, concomitant and retrospectant categories for organizing evidence. Prospectant evidence concerns events that may have occurred before the crime; concomitant evidence concerns events that may have occurred at or near the time of the crime; and retrospectant evidence concerns evidence about events that may have occurred after the crime [Wigmore, 1937]. Most importantly, however, is that the formation of "an event chronology is the first stage in generating stories or scenarios about what might have happened in the matter under investigation," writes Schum, in noting the importance of time as a magnet [Schum, 1999]. The telling of stories, or the generation of scenarios is a most powerful heuristic device in generating new hypotheses or possibilities.

Other marshaling magnets revolve around subjects such as case scenarios and possibilities, "eliminated" hypotheses, and evidential inquiry. There could obviously be many ways of categorizing matters under investigation, each of which could conceivably become a magnet. One can easily imagine the role relational database managers could have in organizing evidence around "key-field" magnets. Event scenarios and possibilities generally allow us to organize evidence around what we think may have happened in the course of the crime, or what conceivably could have happened.

2.2.2 Discovery and Inference: A Closer examination of Abduction and Semiotics

Are there ways to more effectively employ inference and discovery in building testable hypotheses for the scenario environment? Charles Peirce provides insight. He asserted that "this universe is perfused with signs…if it is not composed exclusively of signs" [Sebeok, 1983]. Peirce, and others even more recently, such as Gerald Schroeder, posit that the human mind is the natural interface to read these signs of nature [Schroeder, 2001]. Scenarios that we construct and explore within our minds help us to visualize these

[1] ABEM evidence object-agents graphically depict this observation, a central theme of this research. Also, note that the agents employed in the ABEM model are labeled object-agents in this paper to avoid confusion with the human investigators, such as Special Agents of the Federal Bureau of Investigation or US Army Criminal Investigation Command (CID).

complex relationships between man and nature – Einstein called these *gedanken* experiments. Peirce provided some formalization of the link between discovery and hypothesis in the following statement of reasoning he associated with the inference process he called abduction:

(Premise 1) The surprising fact, *P*, is observed.

(Premise 2) But if *H* were true, *P* would be a matter of course.

(Conclusion) There is reason to suspect that *H* is true. [Tursman, 1987, 13]

In this form, Tursman tells us that Peirce claims that the reason for thinking *H* might be true is that *H* would explain our observation of *P*. In Peirce's explanation, we assume that *H* had not occurred to us before as a hypothesis or explanation for *P* or any other evidence related to this line or reasoning. We only inferred *H* as a possible explanation because of the observance of *P*. In other words, because of the interaction of *P* with other evidence we have been observing, *H* emerges as a possible explanation for *P* and the other evidence we have observed. We likely did not consider *H* prior to the observance of *P*, and in fact discovered *H* as a result of observing *P*. Of course, we must now test *H* to ensure it also serves to explain the other evidence we may have observed prior to *P*. Scenarios are quite useful for this purpose. In addition, the investigator will be eager to see what new lines of evidence *H* allows us to generate. According to Tursman, Peirce notes "that an abduction concludes that such and such a hypothesis may be true and 'that the indications of its being so are sufficient to warrant further examination"[Tursman, 14]. Of course, such continued examination takes place through inquiry and inference, the lifeblood of the ABEM model, as shown below.

There are three basic types of inferential reasoning, each of which is conducive to machine-based support. The following table briefly describes these three types of reasoning methods that decision-makers must seek to master. This table does not, however, attempt to describe the various "shades" or mixtures of inference models that decision-makers might apply. Note that probability, as a means of assessing uncertainty, remains an important element of any study of inference.

Inference Model	Model Assertion	Description	Discovery Potential
Deduction	Normative	Reasoning from General to Specific; "shows what is necessarily so"	Structured, Ordered; Least Potential for Innovation
Induction	Descriptive	Reasoning from Specific to General; "shows what is probably so"; useful for patterns	Less Structured; Intuitive; More Potential for Discovery
Abduction	Heuristic	Inference to a Possible Conclusion; "shows what is possibly so"	Area for Maximum Innovation; A likely *Edge of Chaos*

Let us now assess this table and it's implications for decision-makers. The basic types of inferential reasoning described above rely only on their most basic meaning. *Deduction* is simply a process of reasoning from general knowledge to a specific conclusion. Webster's says "the conclusion follows necessarily from the premises"; if the premises are true, the conclusion must be true [Webster's, 1996, 520]. Deduction, notes Reisberg, is a process by which "we usually begin with a general statement and try to figure out what specific claims follow from it" [Reisberg, 1997, 442]. Deduction might be highly useful in cases where the information space supporting the investigator were "complete" in that it contained all the needed information to support proving a hypothesis, and the premises were consistent with the contents of the information space. This of course is very rarely the case at the onset of matters under investigation.

Induction, on the other hand, is more often applied as a model for probable inference to possible conclusions already generated or discovered [Schum, 1994, 47]. Turning to Webster's once again, we see that induction is a form of reasoning in which the conclusion is supported by, but not necessarily following from, the premises [Webster's, 975]. It is also known as reasoning from the specific to the general. In most cases, induction is the best a decision-maker can do in an imperfect world of missing or inaccurate information. However, induction, (especially when used in agent-based modeling) involves hypotheses that we already have at hand. Also, induction tends to support intuitive thinking, a tool upon which the vast majority of us rely on a daily basis. Reisberg notes, "in induction, we confront a sample of the evidence and seek to extrapolate from this sample" [483].

The final inference method depicted in the chart above is known as *abduction*. Webster's defines abduction as "a syllogism whose major premise is certain, but whose minor premise is probable" [Webster's, 3]. Peirce, the developer of the term abduction as it relates to inference, writes "The first starting of a hypothesis and the entertaining of it, whether as a simple interrogation or with any degree of confidence, is an inferential step which I propose to call *abduction*…" [Buchler, 151]. The importance behind Peirce's thinking is that abduction can simply be a question or hypothesis, in it's relative infancy, but it is more than a mere passing thought; it requires some notion of entertaining that thought in the form of hypothesis, question or idea. In "The Law of Mind", Peirce defines what he believes are the three components of an idea: "intrinsic quality as a feeling," "energy with which it affects other ideas," and "the tendency of an idea to bring along other ideas with it" [Buchler, 344]. Peirce further describes abduction as something that "comes to us like a flash" [304]. He continues, noting that abduction is:

> …an act of *insight*, although extremely fallible insight. It is true that the different elements of the hypothesis were in our minds before; but it is the idea of putting together what we never dreamed of putting together which flashes the new suggestion before our contemplation.

John Holland, et. al. write that abduction is a kind of inference that is routinely used in human thinking, particularly in solving crimes and diagnosing illness [Holland, et. al., 1986]. Abduction essentially involves justification, according to Holland. Josephson and Josephson [1994, 4] write that while deduction is "truth preserving," abduction is "truth producing," and that abduction involves "inference to the best explanation." The Josephsons claim that abductions may display "emergent certainty", a situation where the "conclusion of an abduction can have, and be deserving of, more certainty than any of its premises" [Josephson and Josephson, 15]. Compare this thinking to the accompanying discussions of emergence and it is not a difficult step to link abduction, discovery and emergence as powerful partners that can strongly influence the assessment of results found in agent-based scenarios. In any event, abduction is the process of generating what seems possible [Schum, 1994], and is clearly performed in an area of the investigator's imagination for maximum innovation, or perhaps even a sort of psychological *edge of chaos*. As we have noted, these ideas may also be visualized in the decision-maker's scenarios.

Finally, although not shown in the chart above, agent-based modeling is supportive of the reasoning methods described as a tool for discovery that allows us to *see what happens* or *what could happen*. We sometimes just don't know where to begin in developing our hypotheses or scenarios, or we want to discover patterns and relationships that only complex non-linear, mathematics might reveal. Or, perhaps we want to test our hypotheses in an environment that is less constrained than our pre-conceived notions and prejudices allow – such are the occasions on which agent-based modeling of evidence and interactions may show the greatest value. Compare this claim to Peirce's, Holland's and Schum's thoughts about abduction and ideas above. Interactions of ideas or evidence produce an environment for discovery, revealing what was really there all along but not visible until we could observe the results of the interactions. Holland and other complexity theorists call this *emergence*.

Discovery is important in this description of inference techniques. Discovery clearly involves seeing the world differently—perhaps even seeing things in a way that no one has seen them before. "When asked how he came to discover the theory of relativity, Einstein replied that he imagined how the world would look if he were riding on a beam of light" [Casti, 1997]. In a sense, Einstein not only saw the light, as it were, he became the light—he saw the world differently. If there is a way to introduce some formality into discovery-based thinking, it might be to provide a mechanism to think outside oneself – a scenario, perhaps? Arthur Koestler writes that discovery "often means simply the uncovering of something that has always been there but was hidden from the eye by the blinders of habit" [Koestler, 1964]. Koestler's definition is also supported by the definitions of discover and discovery in Black's Law Dictionary [1990]. Black's definitions discuss the process of learning what was always present but obscured. The machine-assisted process of discovery may be another area where agent-based modeling can aid the investigator in discovering what was always present, but hidden from sight by "the blinders of habit" or prejudice.

3.0 THE AGENT BASED EVIDENCE MARSHALING MODEL: A TOOL FOR DISCOVERY TO ENHANCE SCENARIOS

We now turn to a specific instance of a model that demonstrates the potential of enhancement of discovery in command and control systems through self-organization of data and information. This model, Agent Based Evidence Marshaling, was built on the thesis that self-organizing information systems enhance the process of discovery, and that the dynamic force behind this self-organization could be the simple process of inquiry. As the Schum *MarshalPlan* organized evidence around magnets such as time and location, so ABEM could marshal information, through self-organization, by empowering information to act as a local agent, curious to learn more about its place in the global construct of a scenario or event in question.

Agent-based modeling is a technique to model interactions between object-oriented representations of entities of interest. For example, to model behavior of amino acids involved in building a protein polymer chain in the process of protein replication, an agent-based approach might be to code the amino acids with characteristics that capture their chemical composition such as electrical charge and the ability to interact with ribosomal RNA. The RNA interaction ability would allow the amino acids to recognize a messenger RNA codon that sought a specific amino acid (and not another), in order to build an appropriate polymer chain. Agent-objects might be constructed to represent almost anything. ABEM agents were constructed to represent people as participants and witnesses to a crime, as well as inanimate objects that represented evidence in a crime. In agent-based modeling, emergent global behaviors emanate from the interactions of local agents, who may not even be aware of the global context in which they exist.

ABEM relies on the same process. The object-oriented capabilities of the Java programming language facilitated the development of ABEM, creating information objects, based on coded observations of an investigator into agent-objects capable of certain levels of autonomous interaction. When combined with the reasoning power and expertise of a human investigator, the interactions of the data objects of the ABEM model with the object-oriented autonomous nature of agent-based modeling did in fact produce enhanced potential for discovery. For the full detail on ABEM agent development and interaction, see [Hunt, 2001]. The principal point here is that potential for discovery through uses of agent-based scenarios for command and control also exists and can be inculcated into the NATO COBP.

3.1 Legos™, Technology Graphs and ABEM

In the initial development of efforts of ABEM it seemed straightforward to imagine fundamental observations of evidence as building blocks for hypotheses about an investigation. Chapter 8 of the COPB, Methods and

Tools, describes model federations in terms of Lego™ bricks. The ABEM Model Technology Graph shown below in Figure 2 reflects many of the building block components that Stuart Kauffman generally describes in technology graph ideas he presents in *Investigations* [Kauffman, 2000]. "A set of primitive parts and the transformation of those parts into other objects is a technology graph," notes Kauffman. "Technology graphs concern objects and actions, things and objectives, products and processes in a single framework," he continues [2000, 254]. Figure 2, depicting a precursor model to ABEM called by author James Herriot, "The Chair Model," suggests how objects and actions interact to produce products, such as a chair. This model is also described in *Investigations*.

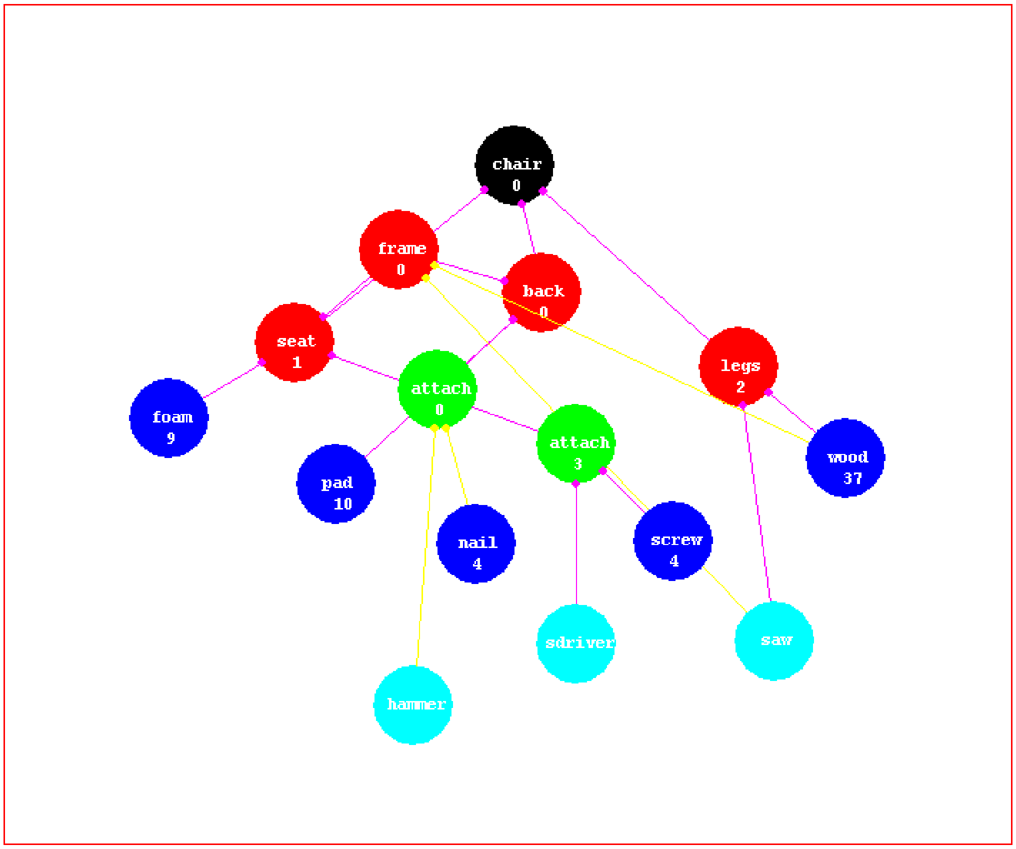

Figure 2.

A "self-organizing chair," depicts relative initial conditions before the construction of a "finished" chair. Like Legos, sub-components *seat*, *frame*, *back* and *legs*, leverage basic components *foam*, *pad*, *nail*, *screw* and *wood* to self-organize and build their sub-assemblies, which will eventually percolate into a final chair product. Note that there are already one *seat* and two *legs* sub-assemblies constructed At the bottom tier are tools *hammer*, *screwdriver (called "sdriver")* and *saw*, that are employed by the *attach* actions in the central part of the model to assemble the components and assemblies. Each of the object-agents has limited knowledge of only their most basic functions, knowing what they "need" (e.g., to be more complete) or what they "have" or "is" (e.g., what they can supply to those in need). *wood*, for example, does not "know" that it is a vital component to the finished *chair*. These agents do not gain experience or knowledge as a result of their interactions (as the agents in ABEM do). *The Chair Model was developed by Dr. James Herriot, Bios Goup, Inc., 2000.*

To express the ideas about technology graphs, Kauffman writes that he invented "Lego World", although my eleven-year-old son, Joshua, and many others like him would likely make similar claims. Regardless of its origins, Stuart Kauffman did demonstrate an extremely important idea with Legos and the environments one of any age can build with them: component objects, when allowed to interact, transform into typically more complex (and often) larger objects. The technology graph-based ABEM seeks to do precisely the same thing: transform evidence, via interaction, into complex scenarios, case theory and eventually testable hypotheses. In the ABEM framework, "objects and actions…" are simultaneously nurtured, and, through autonomous interaction, pointed towards the eventual goal of posing better questions by discovering what is already collected within the evidential database, and predicting what should be contained within it.

Kauffman remarks that the "first thing to notice about the Lego World technology graph is that it might extend off into infinity, given an infinite number of primitive Lego parts" [2000, 224]. This would clearly not be a feature that a criminal investigator or C2 decision-maker would seek to leverage, supposing that she heard this first feature out of context of the remaining thoughts on technology graphs. The key is obviously to keep a check on what can become a primitive part without inhibiting discovery. To constrain this possibility, Kauffman proposes the use of a technology graph grammar such as the *is a*, *needs a*, *has a* grammar construct discussed in Kauffman's *Investigations*. "In Lego World, the grammar is specified by the ways primitive blocks can be attached or unattached, and by any designation of which Lego objects can carry out which primitive construction operations" [*ibid*.] So, grammar constrains combinatorial explosiveness, a significant concern in any model in which many objects are allowed to interoperate in relatively unconstrained fashion.

3.2 A Closer Look at ABEM

Figure 3, below, depicts the basic architecture of the ABEM model, extending beyond the simple grammar-based constraints of the chair model. Reading from bottom to top, the Data Source and DBMS layers describe the traditional methods of organizing data, specifying how ABEM might integrate with existing database systems. The Evidence Marshaling layer defines interfaces to an information organizing strategy such as the Schum-Tillers *MarshalPlan* model. The ABEM Agent Interaction layer describes how agents are constructed and interact through grammar and query, as discussed above. The Scenario Generation layer, perhaps the most interesting aspect of the model for scenario generation and assessment as discussed in Chapter 7 of the COBP, defines how agents interact with each other, the decision-maker and the environment to produce self-organizing scenarios and hypotheses. The final two layers, Hypothesis Formulation and Argument Construction and Testing, describe processes for how decision-makers might interact with the results of the scenarios generated and how these results might be articulated into testable hypotheses and arguments.

The ABEM layers depict relevant sub-component processes that influence the transmittal of information in ABEM from one layer to another and between processes. Thanks to Schum and Tillers, more research of the Evidence Marshaling Layer exists and has been documented as noted. The Agent Interaction and Scenario Generation layers are the primary focus in this paper. The higher layers, Hypothesis Formation and the Argument Construction and Testing are only now being developed by Stuart Kauffman, Bruce Sawhill and Jim Herriot, as part of their work in understanding Boolean expressions as means of expressing complex information relationships [Kauffman, 2000]. All layers, however, are important to an eventual end-to-end ABEM architecture. [See Hunt, 2001 for detailed information about each layer.]

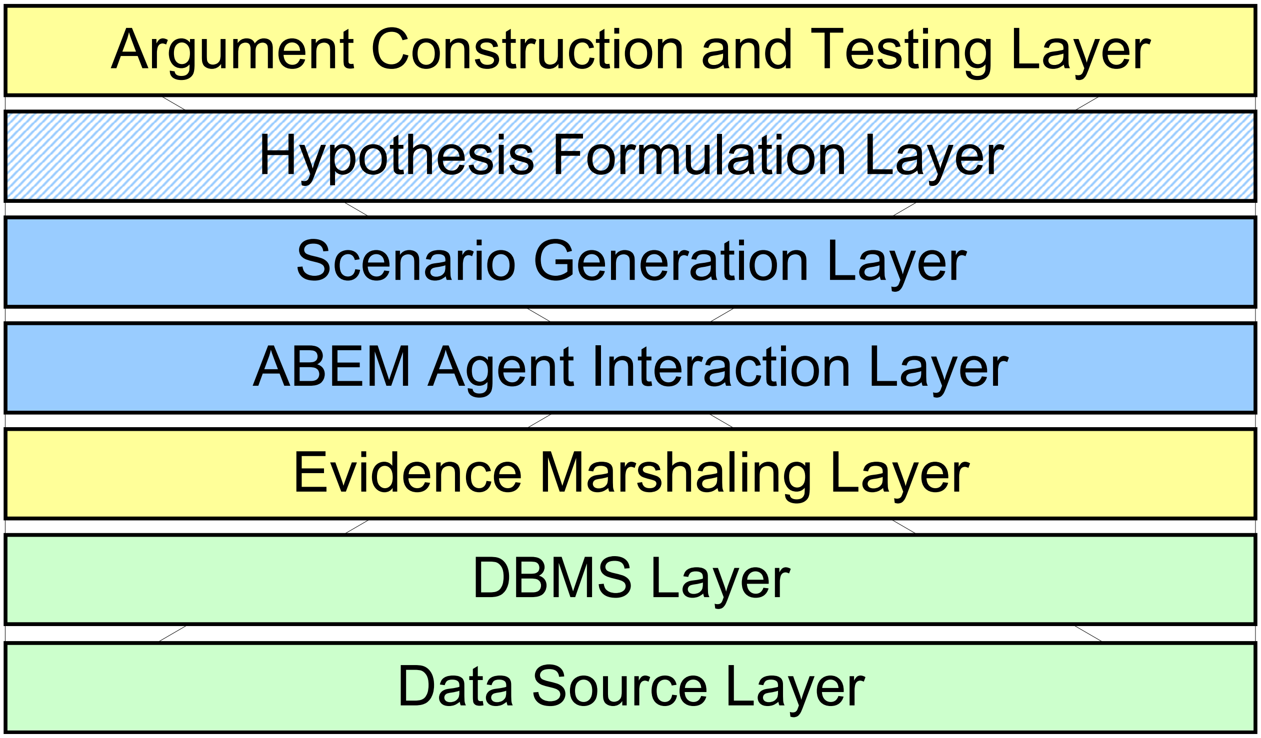

Figure 3: ABEM Architecture.

Before describing the Scenario generation components of ABEM, a brief note about ABEM agents is in order. ABEM evidence object-agents are built upon the tuple construct, a message-passing device. Tuples are also known as tags. Tuples originated with Yale computer scientist David Gelertner and were significantly documented in works produced by Gelertner, Nicholas Carriero and others through the mid-1980s and 1990s. The programming language in which Gelertner specified tuples is called *Linda*. The *Linda* programming language, developed at Yale University by Gelertner, Carriero and others, was introduced as a control and coordination language for parallel and distributed processing. Linda focuses on the creation of activities, the synchronization of these activities and communication among the objects of these activities. It was optimized for parallel processing of single programs [Ciancarini, 1996].

Tuples were originally applied as constructs for improving parallel processing performance in relational database management systems and have had a strong influence in the development of several contemporary proposals for control and accessibility to network appliances and data sources. In the latest applications of distributed networks, such devices pass tuples between each other in their search for information about previously unknown resources on the network. Both Sun Microsystems and IBM have applied tuples as message-passing devices in their *JiniSpaces* and *T-Spaces* research, respectively.[2]

[2] See generally the following papers for more detail on various implementations of tuples and the *Linda* programming language: "JavaSpaces Specifications", Sun Microsystems, Palo Alto, CA, report dated 7/17/98, accessed at: http://chatsubo.javasoft.com/products/javaspaces/specs/js.pdf, accessed on 11/14/2000; and Wykcoff, P., et. al., "T-Spaces", IBM Systems Journal, Volume 37, No. 3, 1998, accessed at: http://www.research.ibm.com/journal/sj/373/wyckoff.html, accessed on 11/14/2000.

ABEM also makes use of similar types of tuples, although in a slightly less structured format to ensure that an environment of maximum flexibility exists. The designer of the ABEM tuple construct, Jim Herriot, removed some of the constraints from Gelertner's original design in order to ensure discovery and inference can take place. Bear in mind that Gelertner and others who have extended his work did not necessarily seek these properties. In the original ABEM work, tuples are utilized to pass information about time and space in order to build vectors for decision-makers to follow more easily.

The Scenario Generation Layer of the ABEM architecture reflects an area of interest for the COBP. Contained within this layer are the components of *substitution*, as well as other grammatical constraints beyond the scope of the current discussion. The concept of *substitution* is of course related closely to Kauffman's description of substitutes (and complements), as presented in *Investigations* [Kauffman, 2000]. While the example below serves to define substitution in the ABEM context, substitutes allow one object to be referred to by another very similar object, following the ideas of semiotics. In the Chair Model case above, a nail might be substituted for a screw when applying the process of fastening two object agents together as a sub-assembly. Substitution is also related to what Marvin Minsky calls "multiple representations," when he expresses what he calls "commonsense thinking" [Minsky, 2000, 71]. As Minsky writes:

> If you understand something in only one way, then you scarcely understand it at all because when something goes wrong, you'll have nowhere to go. But if you use several representations, each integrated with its set of related pieces of knowledge, then when one of them fails you can switch to another. You can turn ideas around in your mind to examine them from different perspectives until you find one that works for you. And that's what we mean by thinking! [Minsky, 67].

ABEM *substitution* does not pretend to empower machine thinking, but it does allow the decision-maker to observe data representation from different perspectives as the object-agents seek substitutes for themselves during the query process. In figure 4, below, an actual ABEM model screenshot, note the interaction between the *truck* object-agent and the *box* object-agent. The initial ABEM model represented in this research attempts to help an Army criminal investigator notionally locate a stolen computer and learn about the identity of the thief. This scenario is documented in detail in [Hunt, 2001].

In the example shown below, object-agent *box* is asking object-agent *truck* if it knows of a substitute, or *multiple representations* in Minskey's terms, for itself. Truck responds affirmatively that it knows about the possibility of a substitutionary relationship of *box* for *truck*. Such a representation is possible for several reasons. The first reason is that the investigator, as he engaged in the early phases of initializing and embedding marshaled evidence, explicitly listed this substitution as possible based on prior knowledge or access to previously collected information in related databases. It is also possible that the object-agent queried the investigator interactively for guidance. The third reason this substitution is possible is based on the notion of *affordance*, the capacity for bearing the "cost" of the relationship.[3] In this example, a truck can "afford" to carry the box, but it is not possible for this box to carry the truck. Such affordance relationships are often useful in avoiding circular relationships that increase the computational burden of search.

[3] This preliminary definition of affordance is based on personal conversations with Stuart Kauffman about constraining the potentially out-of-control activities of object-agents when relying on substitutions to expand the "vision" of these agents engaged in identifying themselves or building relationships with other agents or their environment. See also Axelrod and Cohen [1999, 6], where they define affordance as the feature of non-agent based artifacts that are capable of evoking certain behaviors of agents. According to Axelrod and Cohen, these artifacts are basically objects capable of being used by agents, or objects that can support agent function.

Figure 4 is an actual ABEM screenshot depicting the interactions of two object-agents, *box* and *truck*, as *box* seeks to further identify itself. As shown by the lighter colored arc between the two (with a dotted termination point at *box's location*) *box* queries *truck*, in a random manner, to determine if *truck* knows of any substitutions for itself (shown as "needsa sub box"). *Truck* replies that it knows of a substitutionary relationship, namely that it can be substituted for *box* (shown as "knowsa sub box truck"). *Box* incorporates this information into its knowledge table (as discussed in Figure 5). Box then subsequently begins to build a space-time vector for *truck* since it now "assesses" truck's location to be important. Also in view at the top right corner of the figure is a tuple query from object-agent *Liles*, an agent representation for one of the human witnesses in this case. *Liles* is asking one of the other object-agents for information about his own location at a certain point in time. This question may seem less sensible for "human" agents, but is valuable for inanimate objects such as *box*. *The ABEM Model code was written by Dr. James Herriot, Bios Goup, Inc., 2000.*

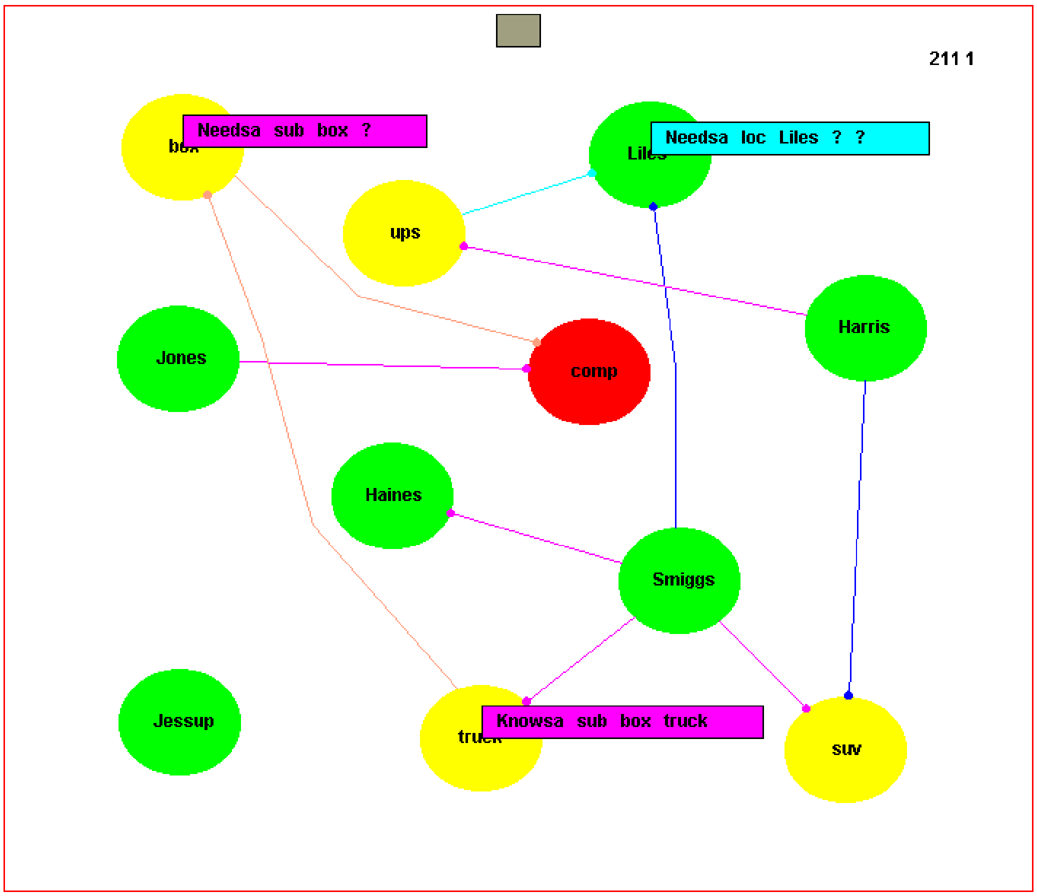

Figure 4.

The substitutionary component of the ABEM Scenario Generation layer empowers what very much appears to be similar to human inference. Noting again the screenshot and description contained in figure 4, it is apparent that the computer object-agent, *comp*, has learned an appropriate substitutionary relationship between itself and *box*. This means that *box* can afford to carry *computer*, as earlier defined by the investigator. Once *computer* has inculcated that information into its knowledge table, as shown above, it begins to fashion queries about the space-time vector and other substitutionary relationships for *box*. In other words, it begins to track *box* because it is now interesting to do so – where *box* is located, *computer* may also be located. Also note that it is desirable for an object-agent to interact with the investigator to ask the investigator if certain substitutionary relationships can exist. The particular example of *box* asking the investigator if it can be a substitute for *computer* is in fact modeled in ABEM. Other grammatical constructs are described in [Hunt, 2001].

Although not shown in the ABEM model run in Figure 4, an object-agent knowledge table captures the tuple-based information with which an object-agent is instantiated as well as new information derived through interaction with other agents. This table captures the results of ABEM object-agents' learning through interaction. Figure 5, below, depicts the likely use of an ABEM knowledge table to build scenarios and hypotheses. The table shown is a reconstruction of the object-agent *computer's* table taken from an ABEM model run. The scenario-generation feature described below, while not currently implemented, suggests how the tuple entries from the knowledge table could be "reverse-parsed", through natural language processing techniques to produce the accompanying scenario. Each of the sentences and phrases to the right of the box are backed up by one or more tuples. The final statement, at the bottom of the scenario, represents a candidate hypothesis that could be extracted from the scenario statement for encoding and testing.

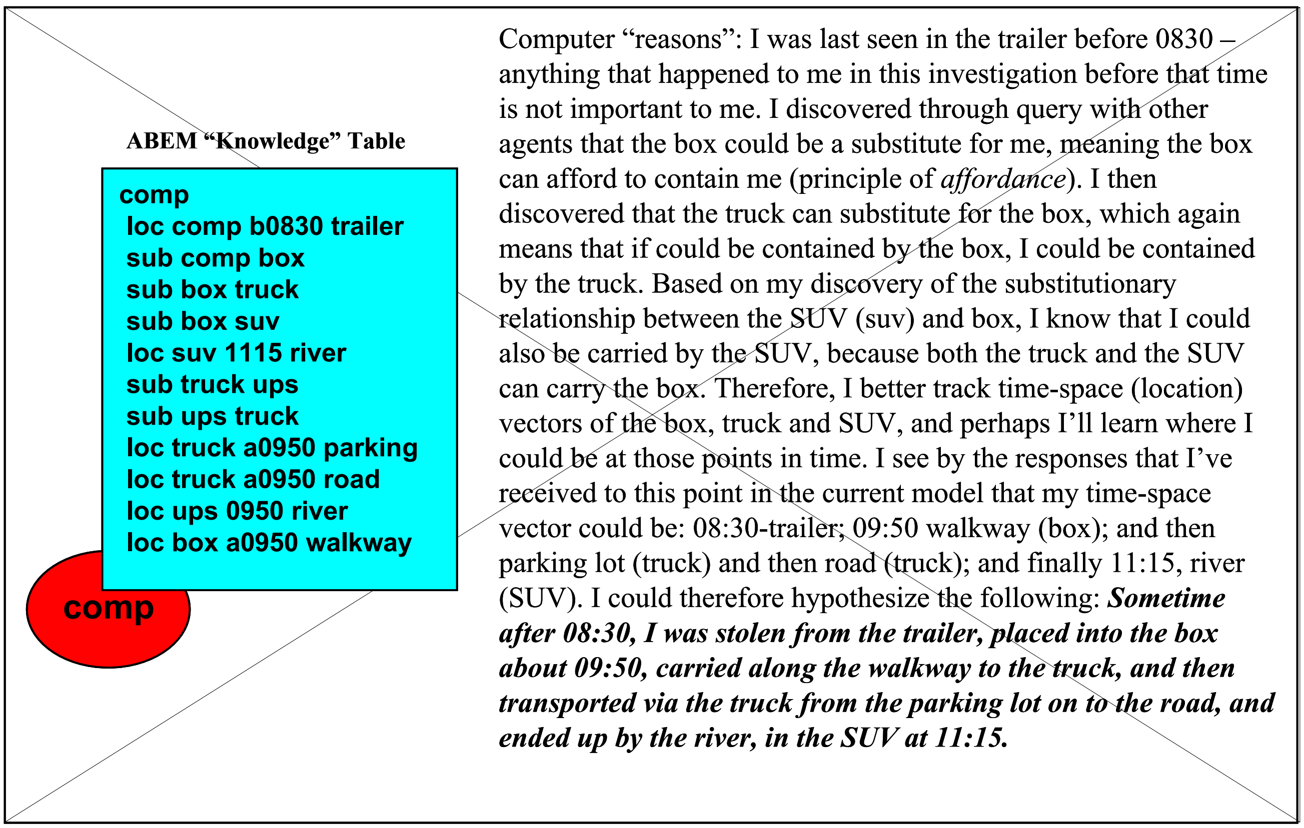

Figure 5: ABEM Knowledge Table Parsing.

The box on the left side depicts an actual emergent ABEM knowledge table constructed from object-agent interactions. The text on the right suggests how the tuples in the knowledge table could be interpreted through natural language processing (a "reverse parsing," perhaps) to build a scenario derived only from agent interactions. The phrase at the bottom of the scenario suggests a more concise hypothesis that could then be coded for testing, as briefly discussed in the ABEM architecture above. For more detail, see [Hunt, 2001].

The principle objective for the original ABEM model was manifested in the development of self-organized scenarios that could suggest tip-offs to what the *unknown unknowns* might be. When examining the agent-assisted scenario at the right of Figure 5, above, for example, a decision-maker might note holes in the chronology or physical space parameters and generate new lines of inquiry based on what she determined to be missing, or unknown. Following the inspiration of the Schum-Tillers *MarshalPlan*, it was of paramount importance to increase the decision-maker's visibility of what was missing that should be part of the puzzle – to instruct on what was not known, but should be known in order to solve the mystery. With the publication of the recent NATO Code of Best Practices, this objective dovetails well with how decision-makers can better interact with scenarios. I now conclude with how ABEM and semiotics might improve this critical process for enhancing C2 best practices.

4.0 ENHANCING C2 BEST PRACTICES WITH ABEM AND SEMIOTICS

Chapter 7 of the NATO Code of Best Practices provides some essential elements of definitions for scenarios within the context of Command and Control. The COBP notes that the composition of a scenario includes a geopolitical context, the various participants involved in a given situation, the overall environment, and the evolution of the events in time. "In C2 assessments, the purpose of scenarios is to ensure that the analysis is informed by the appropriate range of opportunities to observe the relevant variables and their interrelationships," [COBP, Chapter 7, 2001]. As Command and Control assessments involve many non-linear phenomena such as human and organizational behaviours, as well as environmental conditions that transcend human control, linear modeling techniques provide limited insights into the complex relationships that exist between the elements typically modeled in scenarios.

"In essence, the role of a scenario is to define a set of conditions and restrictions to enable 'good' analysis as well as to create a structure within which the results of the analysis can be understood and interpreted," adds the COBP. It is worth noting that the scenario should provide for "good" analysis rather than the "best" analysis. The authors of Chapter 7 of the COBP appear to intuitively understand the parallels of emergent scenarios and evolution. Evolution does not seek the "best" solutions, and neither should scenarios. The purpose of scenarios whether in the context of command and control planning, intelligence or legal analysis or even scientific research, should be to reveal insights about the interactions of objects of interest within a given environment – to facilitate discovery, in other words. The component objects of scenarios, as defined by Chapter 7 of the COBP are good candidates for object-agents in the agent-based modeling world suggested by ABEM.

4.1 Command and Control Best Practices and ABEM

In section 3, I described some basic characteristics of object-agents in general and how these characteristics were manifested in ABEM agents. ABEM agents are software representations of both animate and inanimate objects: participants and witnesses to a crime, as well as vehicles, the stolen computer and various items of testimonial evidence that were a blend of both living and non-living representations. The development of these agents is as much art as science. If a decision-maker is seeking true emergence, she would ensure that the agents were instantiated with enough (but not too much) information in order to interact with other agents and learn. The power of emergent discovery comes from interaction, and the temptation to capture every detail in code for every object-agent must be avoided. Object-agents need just enough information to make them suitable as donors and learners.

The same point applies to Command and Control agent-based modeling. Many of the procedures and bits of intelligence that a planner uses in his efforts are suitable for object-agent encoding. ABEM objects demonstrate how one might encode testimonial evidence and provide for observations of inanimate objects. Might a C2 planner also be able to encode relevant aspects of "best practices" and allow them to interact with fresh intelligence information obtained dynamically from sensors to produce new scenario-based decision-making aids? Apparently, from a reading of the 2001 Code for Best Practices, these new modeling technologies are already under review.

The ABEM model represents a methodology for producing evolutionary, emergent scenarios that can aid in the C2 decision-making process. Evolution is the key word. Life has been successful in the last few billion years because it has found a way to do good things, not necessarily the best things. Seeking the best is expensive and often results in marginal increases in return on investment. This statement does not imply that seeking and sharing "Best Practices" are ill-advised. This is a case of where the journey is more important than the destination. We must seek better ways to defend our national entities and stop aggression before it actually strikes – this is particularly true of terrorism. Given fewer resources than most NATO countries possess, it is highly likely that terrorist forces seek solutions that are good enough to accomplish their mission rather than the "best way." Life works exactly the same way.

Enhancing the process of discovery in planning will result in a certain improvement to C2 best practices. Agent-based modeling, applied in novel ways that produce emergent discovery will augment any planning effort. Understanding the way life and nature work and finding ways to emulate their successes will also improve Command and Control best practices. Mechanistic approaches reflect what's "best" about the way man has typically modeled nature. There's much more to it than that.

4.2 Infusing Command and Control Best Practices with Semiotics

If semiotics is the study of signs and systems that produce and use signs, there are also other ways that nature and the systems that emerge from nature communicate with us. Semiotics scholar Umberto Eco adds two other communications capabilities that nature (including mankind) uses to provide insightful information to us: symptoms and clues. Symptoms, according to Eco, represent deductive methods of communications. "In symptoms the type-expression is a class of ready-made physical events that refer back to the class of their possible causes," [Eco, 1983, 211]. He explains that the pattern of dust on a table, for example, is the symptom that brought about its dispersion or template. A decision-maker can deduce, with confidence, from a symptom to a cause – the presence of the effect or sign the symptom leaves behind is directly tied to the cause.

Clues, on the other hand, notes Eco, are more inductive in nature. "Clues…are objects left by an external agent in the spot where it did something…so that from their actual or possible presence the actual or possible past presence of the agent can be detected." The difference, Eco tells us, is in actual presence versus possible presence:

> In a way clues are complex symptoms, since one must first detect the necessary presence of an indeterminate causing agent and then take this symptom as the clue referring back to a possibly more determined agent—conventionally recognized as the most probable owner of the object left on the spot. That is why a criminal novel is usually more intriguing than the detection of pneumonia. [ibid, 211-212]

Signs, symptoms and clues all feed the process of abduction. The function of probability comes most into play in considering just how much reliance a decision-maker can have in semiotic-based reasoning and discovery.

Eco speculates that in "real" life detectives make more frequent mistakes than scientists because they are "rewarded by society for their impudence in betting on meta-abduction." Peirce defined meta-abduction as wagering on the likely end results without waiting for the results of intermediate observations. Scientists can usually afford to be more patient and test from one intermediate result to the next – their abductions methodically becoming true deductions, where results necessarily follow from observation. C2 planners probably fall somewhere in between, but may lean more toward detectives.

Abductions, in a form Eco calls "undercoded", are "world-creating devices" [ibid, 214]. Such a description sounds a great deal like agent-based modeling. If decision-makers build their models in ways that better harness signs, symptoms and clues (the essentials of semiotics), allowing for interaction and emergence, their models are likely to better represent the nature of the real world and its primary force for change and growth, evolution. If models are appropriate to capture this real-world nature, then agent-based models are likely to be the technique of choice to capture emergence.

Physicist Gerald Schroeder recently wrote that "It is because we are a part of the universe that has become aware," that we have recently been successful at beginning to understand the wisdom contained within even the smallest of the particles that compose nature. "…at every level of complexity, the information that emerges from a structure exceeds the information inherent in the components of that structure" [Schroeder, 2001, 178]. In other words, the ancient maxim "the whole is greater than the sum of its parts" continues to be validated time and again.

Schroeder implies that it is our human mind that uniquely interfaces with nature to produce the understandings that we have of the universe, "a world unrealized at the unconscious level, but still very real in its impact upon the world our conscious physical senses can access" [ibid, 127]. I believe that most semioticians would agree and hasten to point out that it has been the thrust of semiotics to exploit those connections between the mind and nature. For the time being, agent-based modeling, infused with an effective dose of semiotic thinking may be one of the best ways to model those interfaces into nature.

4.3 Conclusions

This paper has examined ways to blend into Command and Control Best Practices more effective use of semiotics, modeling and scenarios. I have shown the agent-based model as a type of novel modeling technique for scenario generation and interaction, as well as infusing into this study some philosophical consideration of semiotics and discovery. I have demonstrated that natural, evolution-mimicking techniques stand ready to enhance the process of discovery and modeling, particularly as it applies to NATO's consideration of best practices in Command and Control planning and execution.

As members of the political and military planning community, we must exercise caution in thinking about our efforts as "revolutionary." Life, as we might observe in agent-based modeling, teaches us the more subtle insights about our role on this earth in terms of evolution. We must adopt the long view, however, in order to see where we actually fit in. The closer we can emulate real life, including how we model it and interact with it, the more likely our successes in complex planning endeavors. The application of agent-based modeling to enhance the process of discovery within our information space will clearly accompany best practices of command and control for the future. Time is short; we should include these practices now.

5.0 REFERENCES

Anderson, T., and Twining, W., "The Trial Lawyer's Standpoint", in *Analysis of Evidence*, Northwestern Press, Chicago, 1991.

Axlerod, R., *The Complexity of Cooperation*, Princeton University Press, Princeton, NJ, 1997.

Bacon, F., *Novum Organum*, "Book II, Aphorisms 2 and 40", Open Court Publishing, Chicago, 1994.

Bak, P., *How Nature Works*, Copernicus, Springer-Verlag, NY, 1996.

Black, C., et. al., *Black's Law Dictionary, Sixth Edition*, West Publishing Co., St. Paul, MN, 1990.

Blackmore, S., *The Meme Machine*, Oxford University Press, Oxford, UK, 1999.

Buchler, J., *Philosophical Writings of Peirce*, Dover Press, NY, 1955.

Carriero, N., and Gelertner, D., *How to Write Parallel Programs: A First Course,* MIT Press, Cambridge, MA, 1990.

Casti, J., *Would-Be Worlds*, John Wiley & Sons, NY, 1997.

Ciancarini, P., et. al., "PageSpace: An Architecture to Coordinate Distributed Applications on the Web", presented at: Fifth International World Wide Web Conference, May 6-10, 1996, Paris, France, accessed at: http://www5conf.inria.fr/fich_html/papers/P5/Overview.html, accessed on 1/15/2001.

Dawkins, R., *The Selfish Gene*, Oxford University Press, Oxford, UK, 1989.

Eco, U, "Horns, Hooves, Insteps: Some Hypotheses on Three Types of Abduction", *The Sign of Three*, Indiana University Press, Bloomington, IN, 1983.

Holland, J., et. al., *Induction*, MIT Press, Cambridge, 1986.

Hunt, C., *Agent Based Evidence Marshaling*, Doctoral Thesis published at George Mason University, Fairfax, VA, 2001.

Josephson, J., and Josephson, S., *Abductive Inference*, Cambridge University Press, Cambridge, 1994.

Kadane, J. and Schum, D., *A Probabilistic Analysis of the Sacco and Vanzetti Evidence*, John Wiley and Sons, NY, 1996.

Kauffman, S., *Investigations*, Oxford University Press, Oxford, UK, 2000.

Koestler, A., *The Act of Creation*, Arkana-Penquin Books, London, 1964.

Minsky, M., "Commonsense-Based Interfaces", Communications of the ACM, Vol. 43, No. 8, August, 2000.

NATO Code of Best Practice for Command and Control Assessment, Revised Edition 2002.

Reisberg, D., *Cognition: Exploring the Science of the Mind*, Norton & Company, NY, 1997.

Sebeok, T., "One, Two, Three Spells UBERTY", *The Sign of Three*, Indiana University Press, Bloomington, IN, 1983.

Schroeder, G., *The Hidden Face of God*, Free Press, NY, 2001.

Schum, D., *Evidential Foundations of Probabilistic Evidence*, John Wiley & Sons, NY, 1994.

Schum, D., "Marshaling Thoughts and Evidence During Fact Investigation", *South Texas Law Review*, Vol. 40, No. 2, Summer, 1999.

Tursman, R., *Peirce's Theory of Scientific Discovery*, Indiana University Press, Bloomington, IN, 1987.

Waldrop, M., *Complexity*, Touchstone Press, NY, 1992.

Webster's New Universal Unabridged Dictionary, Barnes and Noble Books, NY, 1996.

Wigmore, J., *The Science of Judicial Proof as Given by Logic, Psychology, and General Experience, and Illustrated in Judicial Trials*, Little, Brown & Company, Boston, 1937.

Wilson, E., *Consilience: The Unity of Knowledge*, Alfred A. Knopf, NY, 1998.

6.0 LIST OF ACRONYMS

ABEM	Agent Based Evidence Marshaling
ABM	Agent-based modeling
C2	Command and Control
COBP	Code of Best Practices

AUTHOR BIOGRAPHY

Lieutenant Colonel Carl W. Hunt, Ph.D., is the commander of the US Army Criminal Investigation Command's Computer Crime Investigative Unit, and is the organizer and moderator of an annual Smithsonian Institution lecture series on the applications of Complexity Theory in day-to-day life. He has published several papers about the application of agent-based modeling and semiotics to the complex problems associated with making sense of masses of information.

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An Overview of Romanian Command and Control Systems

Col. eng. Stefan Cantaragiu, Ph. D.
Military Equipment and Technologies
Research Agency
P.O. Box 51-16
76550 Bucharest
ROMANIA
Tel.: +40 1 4231483
Fax: +40 1 4231030
scantaragiu@acttm.ro

Lt. eng. Adrian Pascu
Military Equipment and Technologies
Research Agency
P.O. Box 51-16
76550 Bucharest
ROMANIA
Tel.: +40 1 4233053
apascu@acttm.ro

ABSTRACT

Command and control systems make up as a main tool for combat management. Rapid advances in microelectronics, computers, and materials science have put us where we are today. The Military Equipment and Technologies Research Agency had preoccupations in this area, putted across in the development of C2 systems for air, naval and land forces. This paper proposes some reference points about Romanian command and control systems effectiveness.

Key Words: *Command, Control, Effectiveness.*

1.0 INTRODUCTION

In 1973, Romania fielded first Command and Control system in the radar, missiles, aviation and communication domains.

In the past, those devices pioneered advances in the cybernetic approach but this kind of air defence system could no longer cope with high-density coordinated attacks designated to saturate the defence and to overwhelm both surveillance and C2 systems.

It was clear, from the beginning, that fully automated systems were mandatory from initial target detection through fire control and interceptor vectoring, in a very strong contaminated radio and radar environments.

That is why, in 1974, the former Military Institute for Research and Development approached for the first time in Romania, the Command and Control Systems for Air Defence Forces.

The best achievements in the field were Zonal Air Surveillance Centers (ZASCs) and Fighter Command Centers (FCCs), which were already fielded.

The Military Equipment and Technologies Research Agency (METRA), inherited this good legacy and continued the tradition in the C2 field. The METRA's specialists, in cooperation with other American and Romanian technicians, succeeded in putting into service Romanian Air Sovereignty Operation Center (ASOC) at which, soon after that they connected the radars FPS-117 and the systems mentioned above. The System for Naval Combat Management (on the "Mărăşeşti" frigate) will also become operational.

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2.0 ROMANIAN C2 SYSTEMS

The research efforts made by METRA specialists in C2 field leaded to some products which should have been integrated into a unitary national system. After 1989 political trends and defence doctrine changed. This leaded to delays in putting into operational service of manufactured systems.

The main Romanian manufactured C2 systems are the Zonal Air Surveillance Center, the Fighter Control Center and the Naval Combat System.

2.1 Zonal Air Surveillance Center

2.1.1 Destination

The Zonal Air Surveillance Center is designed to integrate 2D analogue radars without plots / tracks generator into a modern surveillance system, using 3D radars with extractors.

2.1.2 Functions

- Surveillance
  - Signal processing from 2D analogue radars and analogue height finder radar;
  - Radar image display.
- **Tracking:** from more sensors simultaneous, with manual initialisation and automatic tracking.
- **Training:** in real or simulated conditions.
- **Back-up:** safe recording of principal data and operator's actions for later analysis.
- **Communications:** provides "order / report" type message traffic with higher echelon and sends zonal air pictures Fighter Control Center.

2.1.3 Components

- Data acquisition device for surveillance radars;
- Data acquisition device for height finder radar;
- Computer for tracking;
- Multi-purpose console;
- Data / voice communication equipment;
- Air conditioning system;
- Independent power supply.

2.1.4 Technical features

- Input data from analogue radars: P-12, P-14, P-18, P-37, 5N87, START-1M;
- Input data from analogue height finder radar: PRV-11, PRV-13, PRV-17;
- Simultaneous connections with:
  - Six 2D radars;
  - Two height finder radar;
  - Fighter Control Center;
- Automatic tracking for 32 tracks.

2.2 Fighter Control Center

2.2.1 Destination

The Fighter Control Center is designed for instrumental and voice command and control of fighter aircraft for long distance interception.

2.2.2 Functions

- Mission control
  - Interception and flight control data processing based on mathematical models;
  - Air picture and flight control data display;
  - Instrumental flight control data composition, codification and transmission;
  - Voice communication for interception control.
- **Training:** in real or simulated conditions.
- **Back-up:** safe recording of the flight control data and operator's actions for later analysis.
- **Communications:** provides "order / report" type message traffic with higher echelon and Zonal Air Surveillance Center.

2.2.3 Components

- Radar data acquisition and processing equipment;
- Height finder radar data acquisition and processing equipment;
- Computer for flight control data processing;
- Multi-purpose consoles;
- Ground to air radio communication equipment;
- Data / voice communication equipment;
- Air conditioning system;
- Independent power supply.

2.2.4 Technical Features

- Instrumental and voice ground flight control for up to 6 fighter aircraft;
- Compatible with the instrumental flight equipment of the: MIG-21, MIG-23, MIG-29 fighter aircraft;
- Simultaneous connections with:
  - Six 2D radars;
  - Two height finder radars;
  - Eight data / voice communication systems;
  - Zonal Air Surveillance Center;
  - Higher echelon.

2.3 Naval Combat System

2.3.1 Destination

The Naval Combat System is designed to provide fight control by an optimised information management based on a radar, sonar, navigation and fire control integration. This system processes and displays data in order to provide a recognized air and maritime picture. Data is collected from surveillance, navigation, sonar and weapons control radar to provide continuous update to a proprietary database maintained on a central computer.

This system is installed on the frigate Marasesti.

2.3.2 Functions

- Data acquisition from sensors;
- Processing and interpretation of the data acquired from sensors;
- Graphical and alphanumerical presentation of the information processed and of the global resulted situation;
- Control of the tactical situation and of missions;
- Fire-control at the firing centres;
- Communications;
- Save / back-up.

2.3.3 Technical and Tactical Features

- Automatic tracking possibilities: 100 targets
- 46 applications of naval kinematics and tactical navigation
- Weapons command-control possibilities: 3 firing centre
- Simultaneous connecting possibilities: naval and air target acquisition radars, navigation radar, navigation sensors, sonar.

3.0 NATO COBP & ROMANIAN C2 SYSTEMS

3.1 Problem Structure

Romanian C2 systems were made in `90-`95 years in a specific geo-political situation. We developed and fielded some C2 systems for air and naval forces that especially focused on providing timely warning of an attack. Previous Romanian studies were valuable source of ideas, data, information, and insight for these systems.

The identification of key C2 systems, doctrine, tactics, techniques and the procedures, the structures and system performance parameters were valid in that period. It is same for the decomposition of the analytic problem into structures, functions, missions, areas, and command levels. In the last years, the structure and character of friendly forces, military chain of command and coalition partners were changed. The consequences upon our C2 systems are significant.

3.2 Human Factors

The benefits from C2 technologies, especially information technologies, are obtained through changes in the training and experience of key personnel. In our case, the organization of training was subsequently to the achievement or implementation of C2 systems, so that we fielded these systems later.

In some C2 systems, we design rules and algorithms for that decision processes requiring the use of "human in the loop". No complex decision-making or command style is modelled.

3.3 Scenarios

In order to provide combat analysis, we crafted operational scenarios for our C2 systems in testing phase. The contents of these scenarios were related to mission objectives, orders of battle, rules of engagement. The C2 elements we addressed in the scenarios include: decision hierarchy of the units under consideration, information flow, communications processes and capabilities (data update rates, reliability, accuracy). Also, the scenarios took in account different echelons of command and the characteristics of information.

3.4 Measures of Merit

According to Code of Best Practice, the established objectives of the evaluation of our C2 system, using Measures of Merit, we considered to be:

- Establishment of expectation of performance;
- Establishment of the bound of performance of the system.

In order to achieve these purposes, the selected measures we used for these systems could be included only in next three levels hierarchy:

- Measures of Effectiveness (the capacity to create an operating picture of the air or naval battlespace, the range at which the sensors are capable to warning, reaction time);
- Measures of Performance (repair or replacement during operation, response times to users, moving with operational units, communications with other C2 systems, response to request within established times, time to train users);
- Dimensional Parameters.

3.5 Models

Especially for operation purposes, we used the deterministic modelling approach for our C2 systems. Extremely simple models were designed in order to establish the technical capabilities objectives. No other modelling approach was used. These models we created were verified and validated using real experiments.

4.0 CONCLUSIONS

The current military environment, in term of C2 systems, can be characterized by new factors as:

- The managerial and technological advance of the NATO community in the field, which implies significant own efforts, including financial ones, to align our systems with the modern ones, to achieve the competitive and interoperability;
- The C2 systems became the main targets for potential enemy attacks;

- The modern C2 systems should be based on the same principles and the same operational philosophy;
- The globalisation of the access and information processing;
- The unexpected restrictions imposed by the providers related to information access and the state of the art technologies;
- The omnipresence of the decision making act, unconditioned by time or space;
- Almost real time reaction of military systems.

The cumulative impact of the above mentioned factors shall influence the process of designing, developing and testing C2 systems.

The access to the state of the art technologies and the cooperation with NATO and PfP countries underlined the necessity to develop Romanian systems in order to achieve the interoperability with the similar NATO/PfP systems.

In order to develop C2 systems able to supply intelligent support for commanders, new methods should be developed to recognize the analytic request importance. The recent emphasis on prototyping is consistent with evolutionary development requirements and is likely to become an essential step in the C2 systems design process. The evolutionary development is a concept that originates in high technology, doctrine, cost-effectiveness relationship and "try-before-buy" strategy. The relationship between the doctrine and C2 systems development must be permanently examined.

The evaluation must be the first step and the tests must be gradually run as long as our C2 systems are developed, but not after they are already in production. Certainly, one of the problems is the trust we have in C2 simulation environment to test our systems, these environment may or not may be enough closed to the real conditions in order to make more credible the evaluation.

The evaluation of our C2 systems is impossible without addressing the way they can interact with our partner systems (future allies) and how they can affect the potential enemy systems.

In conclusion, it should be mentioned that the developing of Romanian C2 systems and the procurement of other systems represent a priority of Romanian Army, that being the reason why it exists a very favourable climate for new initiatives and concepts in this field.

Finally, we like to point following aspects:

- The solutions for more rapid improvements to our C2 capabilities are not simple and will require an important financial effort;
- C2 is a military operational problem that will not be solved without a deep and persistent involvement in the requirements, resource allocation, acquisition, and testing process;
- Inherent risks in the increasing dependence of combat doctrine upon survivable C2 must be demonstrated to commanders by simulations and exercises that place realistic stress upon C2 systems;
- Evolutionary acquisitions and the leveraging of commercial information systems technology are proven means to satisfy most military C2 requirements and they are probably the only ways to lower costs and produce near term improvements substantially.

5.0 REFERENCES

NATO Code of Best Practice for Analysis of Command and Control in Post Cold War NATO Missions.

Johnson, S.E., Lewis A.H. (1986), Science of command and control, Coping with complexity, AFCEA International Press.

Ince A.N., Evrendilek C., Wilhelmsen D., Gezer F. (1997), Planning and architectural design of modern command, control, communications and information systems, Kluwer Academic Publishers.

6.0 LIST OF ACRONYMS

ASOC	Air Sovereignty Operation Center
C2	Command and Control (Systems)
FCC	Fighter Control Center
METRA	Military Equipment and Technologies Research Agency
ZASC	Zonal Air Surveillance Center

AUTHOR BIOGRAPHY

Stefan Cantaragiu is General Manager of the Military Equipment and Technologies Research Agency from 1999. He is an expert in radiotechnics and radiocommunications and has a Ph. D. from Military Technical Academy, Bucharest. He has numerous works in the field of research management and radiotechnics (microwaves circuits, antennas and propagation).

Adrian Pascu is a scientific researcher at METRA. He has published two papers in radar field and three papers concerning data quality for informatics systems. He's current works are in the field of Romanian C2 systems.

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Working Towards Information Superiority: Application Coherence for Digitisation Programmes – A Method for Coherently Defining Requirements for Future Command and Control Information Systems

Kees van Haperen, MSc
Hi-Q Systems Ltd.
The Barn, Micheldever Station
Winchester
Hampshire SO21 3AR
UNITED KINGDOM

ABSTRACT

Within the UK, a conceptual model has been developed which represents the main processes of the Army, i.e. the Army Activity Model (AAM). It predominantly illustrates information dependencies between processes and information elements that are exchanged between them. Over the last 18 months, the AAM has significantly matured. Moreover, there is a better understanding of its relevance for current and future Information Systems. A methodology has recently been developed that enables the richness of the AAM to be exploited for developing new C2 Information Systems (IS). By using this methodology coherent development and definition of user requirements can be achieved. In addition, the methodology enables, albeit at a high level, the assessment of coherence between C2IS and, more specifically, the processes and information that these systems support.

Using a UK Case Study based on the development of a Joint Fire Support (JFS) Battlefield Information System Application (BISA), it is explained how the methodology allows the use of the AAM for development of new CCIS. It is explained how various Soft Systems Methodology (SSM) and Modelling techniques helped to relate the JFS BISA to the AAM and define or validate coherent user requirements. Using the AAM, application coherence can be assessed and visualised at both informatics as well as technology levels. Although such assessments are conducted at a high level, they nevertheless provide detailed information on gaps and overlaps in the definition of IS requirements. This information could be used to improve requirements definition and aid coherent and interoperable system development. Finally, the paper will attempt to contrast the application coherence method with the COBP.

Key Words: *Command and Control Information Systems, application coherence, soft systems methodology, information superiority, requirements derivation.*

1.0 INTRODUCTION

There is a danger of misalignment between applications and the businesses they purport to support and, through a lack of strategic direction, a risk that bespoke and stovepipe Information System (IS) development will continue. There is concern that there is a potential lack of coherence across, and within, Battlefield Information System programmes. Not only may this result in an inability to transfer data and information effectively between battlefield applications, it will seriously degrade the ability to exploit information and will impede the achievement of information superiority.

Within the UK, a conceptual model has been developed which represents the main processes of the Army, i.e. the DINF(A) Army Activity Model (AAM) – which has been presented at previous editions of this

Paper presented at the RTO SAS Symposium on "Analysis of the Military Effectiveness of Future C2 Concepts and Systems", held at NC3A, The Hague, The Netherlands, 23-25 April 2002, and published in RTO-MP-117.

Symposium. It has been explained that the AAM predominantly illustrates information dependencies between processes and sub-processes, and information elements that are exchanged between them. Over the last 18 months, the AAM has significantly matured. Moreover, there is a better understanding of its relevance for current and future Information Systems. A methodology has recently been developed that enables the richness of the AAM to be exploited when developing new Command and Control Information Systems. By using this methodology coherent development and definition of user requirements can be achieved. In addition, the methodology enables, albeit at a high level, the assessment of coherence between C2 Information Systems and, more specifically, the processes and information that these information systems support.

This paper explains how the methodology allows the use of the AAM for development of new CCIS. Using a UK Case Study based on the development of a Joint Fire Support (JFS) Battlefield Information System Application (BISA), it is explained how various Soft Systems Methodology (SSM) and Modelling techniques helped to relate the JFS BISA to the AAM and to define coherent user requirements. It is also explained that this approach enables coherent development of system requirements. Moreover, the paper will explain how, through the use of the AAM, application coherence can be assessed and visualised at both informatics as well as technology levels; this method is known as COVIS i/t. Although such assessments are conducted at a high level, they may nevertheless provide detailed information on gaps and overlaps in the definition of Information System requirements, especially with regard to the processes they are to support. This information could be used to improve requirements definition and aid coherent and interoperable system development. Finally, the paper will attempt to contrast the application coherence method with the COBP.

2.0 ANSWERING THE CHALLENGES OF DIGITISATION

2.1 The Information Age

Through history, societies have been confronted by continuously improving military technology and the challenge to innovate their defence systems. Evidently, nations need to cope with new threats and prepare accordingly. Nevertheless, history also shows that nations – especially when experiencing times of great prosperity – may be tempted to discontinue their investments especially when the belief increases that conflicts can be resolved in other ways. In the 3rd Century BC, when discussing the necessity of walls around cities, Aristotle (1992), in pointing to ‘modern improvements in the accuracy of missiles and artillery for attacking a besieged town’, already warned for the potential catastrophe of omitting strong walls. That the intention of this ancient advice has not lost its significance is underlined by the current geo-political situation.

Militarily, we are now facing the challenges of ‘information-age warfare’; many NATO Allies are currently implementing a digitisation programme in some form or shape. It is commonly envisaged that armed forces can be transformed into a smoothly operating synchronised system, very like a fine tuned machine. Behind this idea is the fundamental assumption that the friction of warfare will be automatically ameliorated or eliminated by effective acquisition and transmission of information that has been transformed into appropriate command knowledge. By effectively using information, armed forces will be able to move quickly and attack an enemy simultaneously in multiple dimensions, overwhelming the opposing side’s ability to control operations and to frustrate ‘our’ objectives; moreover, it is believed that by mastering information, operations can potentially be commanded at an operational tempo that no potential enemy can match (PAM, 1994). The concept of information superiority seeks to ensure that the peacekeepers and warfighters receive the right information at the right time to optimally influence the outcome of an operation.

However, with the focus on an ‘information centric’ approach, the development and introduction of command and control or battlefield information systems faces many challenges of which some have long been known while others have only recently emerged. Traditional system development and engineering methods no longer suffice while for operational analysis – as is highlighted in the NATO Code of Best Practice (COBP) for Command and Control assessment – more qualitative methods and techniques need to be embraced. An evolutionary relationship exists between the methodologies and techniques used to define requirements, to design and develop the system and to assess its operational effectiveness. Therefore, it could be argued that if these methodologies and techniques were to be adopted in the requirements, design and development stages of new systems they could in turn alleviate some of the shortfalls of operational analysis. In the following paragraphs some of the issues associated with digitisation and related to characteristics of organisations, information, and information systems will be highlighted, which underpin the necessity for a novel approach.

2.2 The Need for a Different Approach

In '*Vom Kriege*' von Clausewitz (1982) explains that information is the knowledge one possesses of the enemy and his land, and that this constitutes the foundation for all our own ideas and actions. He warns that when considering the nature of this foundation, especially the unreliability and changeability thereof, it rapidly becomes clear how dangerous and fragile the framework of warfare is and how it could bury us under its rubble; information or intelligence during wartime is contradictory, an even larger portion incorrect and the largest part extremely dubious. Scholars from other fields of expertise, such as the public administration and political science, have found that information during crisis situations can be confusing, untrustworthy, incomplete, inaccurate, et al. 't Hart (1993) highlights that during crises decision-makers face both information 'underload' as well as overload. It is hardly sufficient to conclude that with digitisation, or the development and implementation of information systems and technology that support the conduct of warfare, we are facing some complicated issues. Albeit tempting, these issues cannot be resolved by engineering alone nor by simply introducing hardware and software.

Nevertheless, as is highlighted in the NATO COBP (2002), the focus of military research has predominantly been on the physical domain. It is further stated, that because Command and Control deals with distributed teams of humans operating under stress and in a variety of other operating conditions, Command and Control problems are dominated by their information, behavioural and cognitive aspects, which are less well researched and understood. As is highlighted by Checkland and Holwell (1998), organisations are often seen as goal-seeking machines where individual decision-making occurs to achieve these goals. However, from an information aspect system such a view is too limited. Traditionally, engineering, development and design approaches have not embodied the kind of in-depth exploration of organisational thinking which is necessary if information requirements are to be richly captured. They argue that a change of focus from data processing towards people and processes which the system serves and supports would then be necessary. Inevitably, in the goal-seeking organisation, like a machine, people are seen as automatons that will deliver *sine qua non*. In contrast, real organisations are characterised by permanent debates about aims and how best to achieve them and are staffed by real people whose perceptions of the world never coincide exactly, and certainly not with any notional worldview which is that of the abstraction 'organisation'.

In '*Trapped in the Net*', Gene Rochlin (1997) points to the unanticipated consequences of an ever increasing computerisation and the introduction of more and greater computing power. Using examples such as the case of USS Vincennes and the shooting down of the Iranian airliner, he explains that many of these consequences have a human or organisational origin. Moreover, the organisation that introduces, or improves its existing, information system technology should not ignore the fact that the way in which it operates may be altered significantly and to such a point that cannot be imagined up front. Checkland and Holwell (1998) highlight that at an operational level new technology would bring changes to the design process and working practices would be changed. With the introduction of a new information system not only the organisation, but also its agents and technology will be changing individually and while at the same time affecting each other. If the organisation is to absorb the technological, organisational and social changes successfully, it should consciously conceptualise these elements and their interactions as a 'whole'. Using merely a 'hard' approach and solution would ignore these and it would remain questionable – the least – whether such a solution would ever be effective. Wilson (1990) highlights that organisations, rather than dealing with 'how' to solve a problem, firstly should concern themselves with determining 'what' the problem is. The 'spiral development' methodology applied in the Task Force XXI programme recognises that new technology might potentially effectuate changes to doctrine, organisation, et al. In turn, these changes might shape and steer further development.

Worm (2001) highlights that 'adequate performance in complex, high-risk, tactical operations requires support by highly capable management'. He states that 'commanders and senior decision-makers must manage true real-time properties at all levels: individual, stand-alone technical systems, high-order integrated socio-technical systems and forces for joint operations alike'. Measuring performance, developing systems and conducting operational testing that cope with such complex conditions are a challenge. Moreover, Command and Control, tactics, techniques procedures and training are forced to constantly and concurrently strive for perfection. However, as is stated by Worm, this is beyond reach unless novel cutting edge solutions can support the humans and systems engaged.

Digitising armed forces is like transforming them into a smoothly operating system, which requires traditionally disparate elements to be linked or networked into one single whole, or a system of systems. The desire to do more with less is a major factor driving this transformation. Consequently, much of the slack in a traditional army will disappear, while operations are sustained by just in time logistics processing. The availability of information technology will give senior commanders a real-time 'god's-eye' view of the battlefield and enable them to plan, task and execute operations. To respond dynamically to developments on the battlefield, communication lines may pervade the more traditional hierarchical structures. Most armies have never experienced such significant organisational changes as introduced by digitisation. From an organisational perspective it is not only paramount that the complex myriad of systems is not only capable of sharing and exchanging information between systems, as has been the traditional focus, but also support the processes of the organisation in a coherent manner.

There is a growing realisation that a meticulously planned, integrated command and control information infrastructure is desirable. Information integration provides the mechanisms to transform data into information and information into knowledge. However, there is a danger that as a result of decentralisation of acquisition processes and a lack of co-ordination between programmes, infrastructures, communication systems and networks may be inadequate to support the information enterprise. Beckner (2000) highlights that communication systems and networks are inadequately managed because the information needs of the users are poorly defined. Over the past few years much effort has been devoted to develop C2 and information architectures that define relationships between entities, their information systems and exchange mechanisms. The main goal of an information architecture is to define for its components 'what is needed', 'when it is needed' and 'how to interface'. The US C4ISR Architecture Framework is proof that the value of architecture products to define present and future needs is realised. However, as is highlighted by Breckner (2000), despite this architecture framework a major challenge remains in focussing on information content and use. Moreover, although much is done to assess architectures, e.g., their effectiveness, this remains a complex task. Often architectures are incomplete in that certain products do not exist and creating them especially for large architectures may not be a realistic option (McBeth, 2000). Consequently, there is a risk that the apparent inadequacy of these architectures may fail to resolve some of the intricacies of defining and developing new systems.

2.3 Soft Systems Methodology

The issues discussed above represent some of the major challenges of digitisation. It has been highlighted that the problem situation is complex and that a route to a solution would need to embrace organisational, human and technological aspects. Major challenges exist in that the information needs of users are poorly defined. Yet, information is a commodity whose timeliness and use is paramount to success between operational nodes at every level of every organisation (Beckner, 2000). C2 and information architectures help to define current and future information needs and have therefore helped to ameliorate the situation. Unfortunately, architectures still lack a focus on information content and use. Soft systems methodology (SSM) offers a way to make sense of such complicated problems and adopts an information centric stance, while including human issues from the outset.

SSM, itself is a method for resolving problems and assists in understanding the many simultaneous views which may exist on what an organisation is trying to achieve. This allows potential interfaces to a system and factors that influence system implementation to be investigated thoroughly. SSM is particular useful where business requirements are unclear, conflicting interests exist, or the proposed system is contentious. Moreover, SSM may be applied to good effect where changes to business processes or organisational structure are likely (CCTA, 1993). SSM is based on the premise that information systems exist to serve and support people taking purposeful action. This purposeful action can be expressed via activity models, to which SSM terminology refers to as ‘Human Activity Systems’ (Checkland and Holwell, 1998). Checkland and Scholes (1999) explain that SSM offers a process through which an organisation can continually reflect upon its aspirations and tasks, thus continually reviewing its information strategy; using the methods of SSM activity systems could be modelled and the models used in a design mode to ensure that processes are institutionalised by means which the organisation would continue to learn from its flow of experience. It is noted, though, that SSM may be used to complement other approaches, e.g., SSADM and System Dynamics, rather than replacing them. The advantage of applying SSM is that it encourages the analysts to concentrate on the business environment, while considering the area under study in the context of the whole organisation and acknowledging multiple perceptions of which some may conflict. The UK Army has been successfully using SSM techniques to construct coherent views of its processes and the information dependencies between them. From the initial modelling activities an approach has now emerged to assess whether and how existing and future information systems support the processes of the Army information enterprise. This method, referred to as ‘application coherence’ (Hi-Q Systems, 2001) is explained in the following paragraphs.

3.0 APPLICATION COHERENCE

It is thought that there is poor alignment between processes and the supporting applications and little coherence between the numerous planned and in-service information. This can be attributed to, albeit in part, a lack of definition in the underpinning information architecture, against which an information strategy can be defined, and a lack of clarity regarding application and process proponency. However, it will be argued that the development of information systems could be rationalised by focussing on information and application coherence, which would improve resourcing efficiency, enhance operational effectiveness, and improve information exploitation.

Addressing applications coherence is a complex, multifaceted system of problems. The problem of improving application coherence is not one of software integration, but one of developing and maintaining an information view of processes, applications and their inter-relationship. The starting point is to take a view of the Army ‘business’[1] and divide that into a coherent set of ‘business areas’ (see Figure 1).

[1] The term ‘business’ has been selected as a neutral way of referring to a superset of purposeful processes supporting ‘Army’ and is, of itself, purposeful. A ‘business’ area is a further neutral term user to describe a smaller set of processes grouped together to achieve some particular purpose.

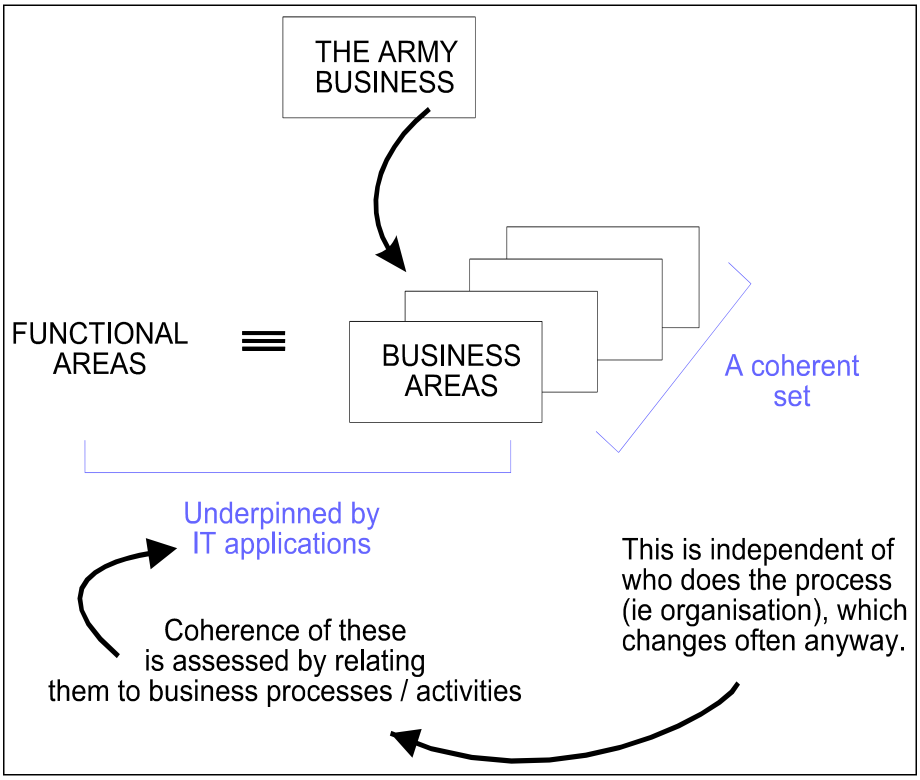

Figure 1: How to Assess Coherence.

Coherence of the business area set is important. A coherent view of process is traditionally delivered through an integrated business model. In the case of the UK Army/DINF(A), this is the Army Activity Model (AAM)[2], (Figure 2) which defines business areas as 'functional areas' (Figure 3). The business or functional areas provide the 'targets' for coherence analysis, whilst aggregated, describing the whole Army 'business'.

[2] The UK Army has developed a complete view of what it takes the Army 'to be' in the conceptual Army Activity Model which has been presented previously to this symposium as the Single Army Activity Model (SAAM) or Army Operational Architecture (AOA).

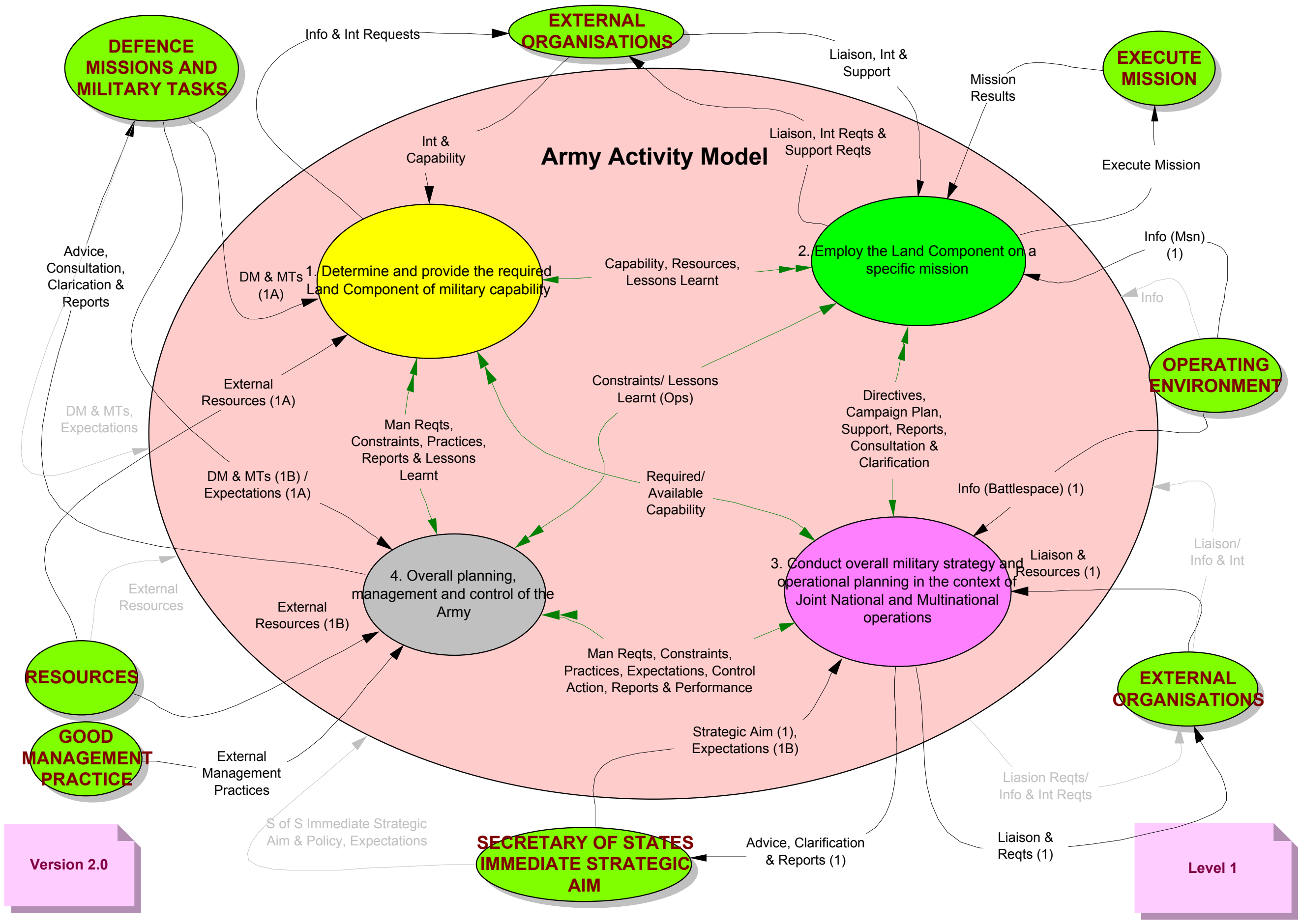

Figure 2: Army Activity Model.

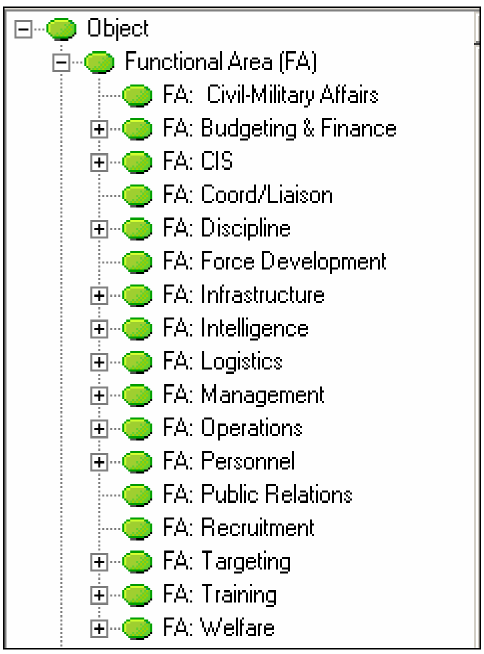

Figure 3: Functional Areas.

Coherence is about synergy and is manifest in the identification of gaps and overlaps in target systems. Information driven analysis will identify these, both in the information available to support processes, and in the ability of applications to support information requirements. Gaps and overlaps in application coverage, individually or in sets, will also be evident.

At a high level of abstraction, an illustration of information analysis is shown in Figure 4. The figure shows, a business area, triggered by a real world problem, being analysed in terms of its supporting activities and the applications designed, or thought to, support it. The purpose of using a conceptual reference for processes is the certain knowledge that a set so derived is coherent. When conceptual processes are used, decomposition at the data level will, perforce, be informed by domain language. Activities and applications are analysed to reveal their information content referred to by the generic term 'information object'. Refinement of this analysis shows that these 'objects' will need further categorisation into 'information products' (IPs) and 'information categories' (ICs). If associations between objects in these two lists are readily apparent, then the degree of correlation can be used in coherence assessment at this level. If the association is unclear, because of differences in semantics, then further decomposition of objects to data content and data sets is required. This continues until associations are clear. In addition, tests of coherence will be complemented by an assessment of technical interoperability criteria.

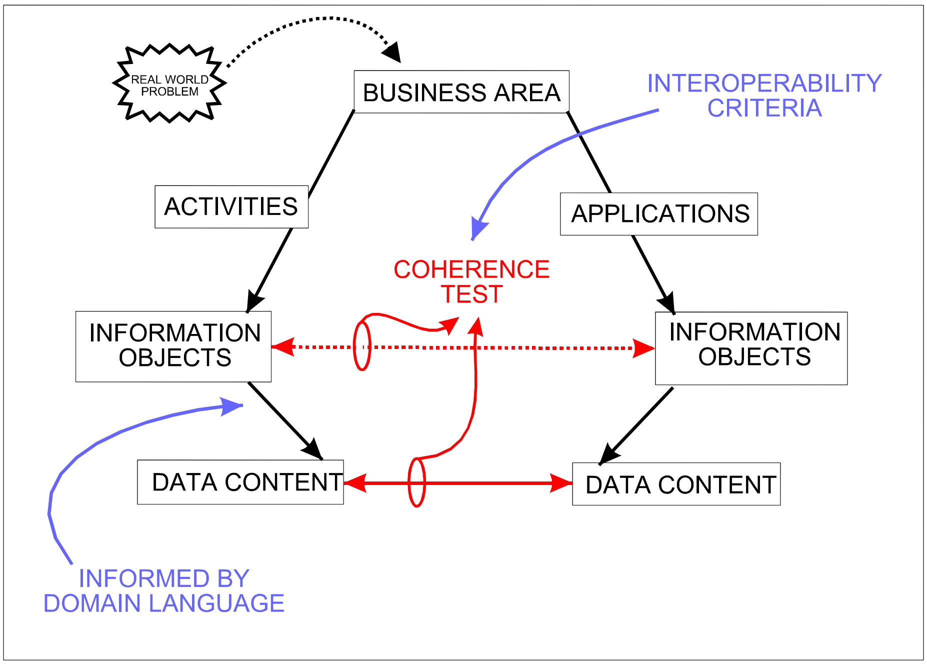

Figure 4: Illustration of Information Analysis.

In this paper, the term 'information category' refers to elements of information that need to be 'known about' in order to conduct a CP. The term 'information product' refers to the real-world IPs that are consumed by, and are produced by IS. These IS' may be automated, that is hosted on a computer system, or may be hosted by a human. The fundamental hypothesis underpinning the coherence assessment method is that information categories derived from processes defined in a coherent process model when correlated with ICs contained in IPs derived from applications will inform the coherence assessment of an application set. Similarly, ICs derived from RWA will inform the coherence assessment for RWA. At a higher level, ICs contained in IPs consumed or produced by an organisation will inform the coherence assessment of an organisation.[3]

[3] It is, however, likely that IPs related to an organisation (ORBAT element) will be derived from the RWAs it conducts.

There is a warning associated with this type of thinking; it is only two-dimensional (process-information/application). Two disadvantages may apparent:

a) Applications that pass the current test (in this case the criteria is 'coherence') may be chosen, rather than those 'best of breed'.

b) Changes to the information architecture become difficult since they need to be propagated and validated across all the applications and the business culture. One answer is to cluster applications. The AAM takes this sort of approach with its annotation of process and application with 'functional area' from a defined set. Each cluster is detailed and closely coupled (e.g., within 'logistics' or within 'intelligence'), whilst coupling between clusters (e.g., between 'logistics' and 'intelligence') is weak. In a coherent solution, clustering should run from the business area right through the information model to the applications.

An organisational view is not essential to an assessment of application coherence but, nonetheless, may be allowed to contribute an important additional dimension. The 'organisation' is important in the design of a capability[4] because it provides influences through its size, its physical layout (an important factor in a dispersed battle-space for example) and the level of trust between its elements. In particular, organisation defines the relative scope of the configuration management activity and information/data management boundaries. 'Organisation' influences, and often seeks to control, the clustering of process and application. The software integration challenge will affect the feasibility and cost of coherence delivery. Coherence is also a function of the design of the IT applications and an assessment cannot be completed through the comparison of two information-based strands alone.

Combining the information-based assessment with technology related assessments would enable analysis to take a more substantial architectural approach. By attributing certain qualities to information exchange technology used by particular applications, systems or platforms it would be possible to create a more complete picture of the level and degree of coherence. The example below (see Figure 5) shows mapping of real world systems to the AAM processes through the mapping of AAM ICs with the applications' IPs. By comparing the two RW applications it can be determined which processes and activities the two applications have in common. Subsequently, it can be assessed which IPs the two applications share that could support information exchange or could share provided that some translation or conversion (technological or procedural) would occur. In other words, although the applications perform or support similar processes it may not be possible to support information exchange other than through voice communication or swivel-chair translations. Finally, by assessing the particular interface hardware and software of each application and the available communication network it would be possible to determine whether technical connectivity can be achieved and whether limitations apply; for instance one application may be equipped with a different encryption device, or an application may only be capable of simplex data exchange, etc. The UK Army is currently undertaking further research into the development of a method that combines assessment of coherence at informatics as well as technology levels.

[4] Capability may be thought about as sets of process, resource and organisation. The role of organisation is to control the production and consumption of resource by process. Process holds purpose.

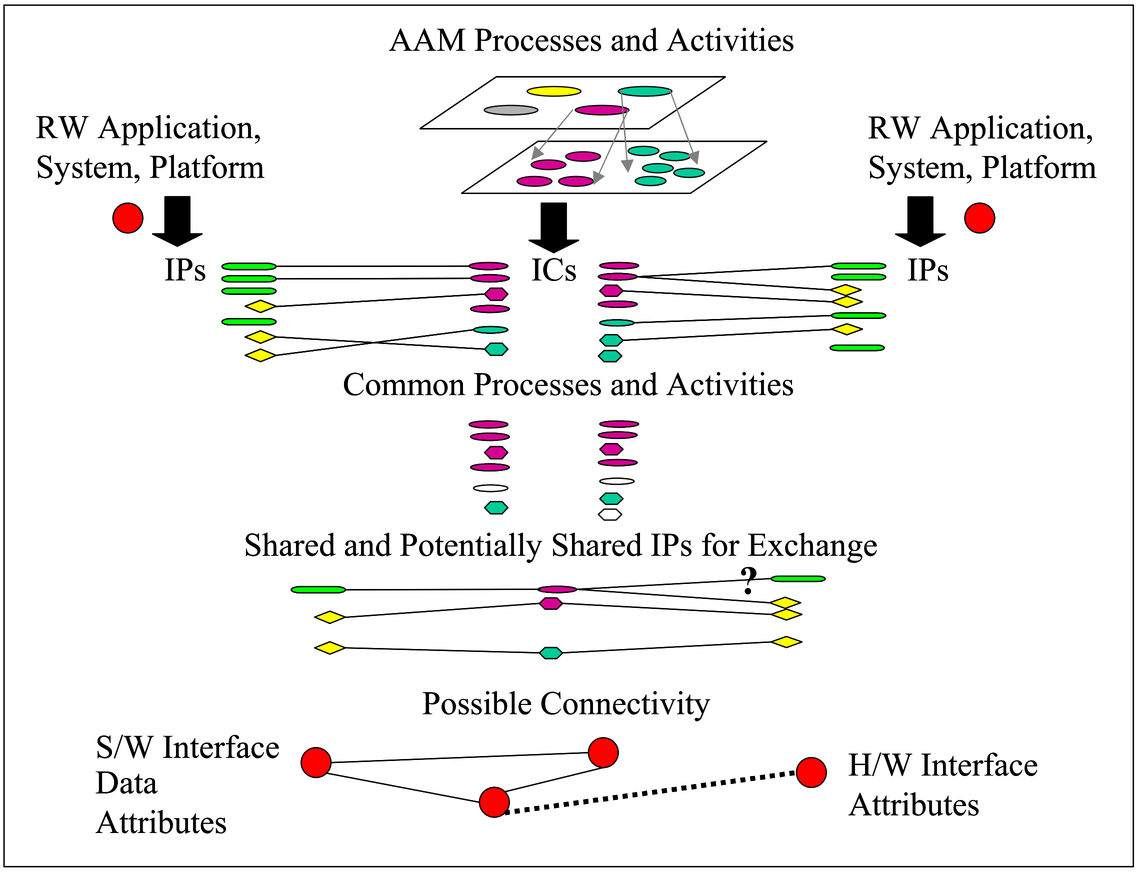

Figure 5: Assessing Coherence between Systems at Different Levels.

4.0 THE APPLICATION COHERENCE METHOD FOR NEW PROGRAMMES

4.1 The Joint Fire Support BISA Case Study

One of the UK Army's most recent programmes is the development of a BISA for Joint Fire Support (JFS). Early in the programme it was decided that the AAM would be of relevance to JFS and commensurate with the principles of application coherence, a method was sought which would enable the richness of the AAM to be used for JFS. It was decided that a number of activities had to be undertaken to capture the JFS requirements in such a way which would enable exploitation of the AAM. Various steps were taken to develop a conceptual model for JFS to analyse the degree of applicability of the AAM. The process model assembly has been achieved by applying various Soft Systems Methodology (SSM) techniques. The following paragraphs give a brief overview of the methodology describing the various phases that were adopted (Stage 1A, B and 2).

Based on the current understanding of Joint Fire Support (JFS) a conceptual template (Figure 6) for JFS was created, which was used for the planning of subsequent activities.

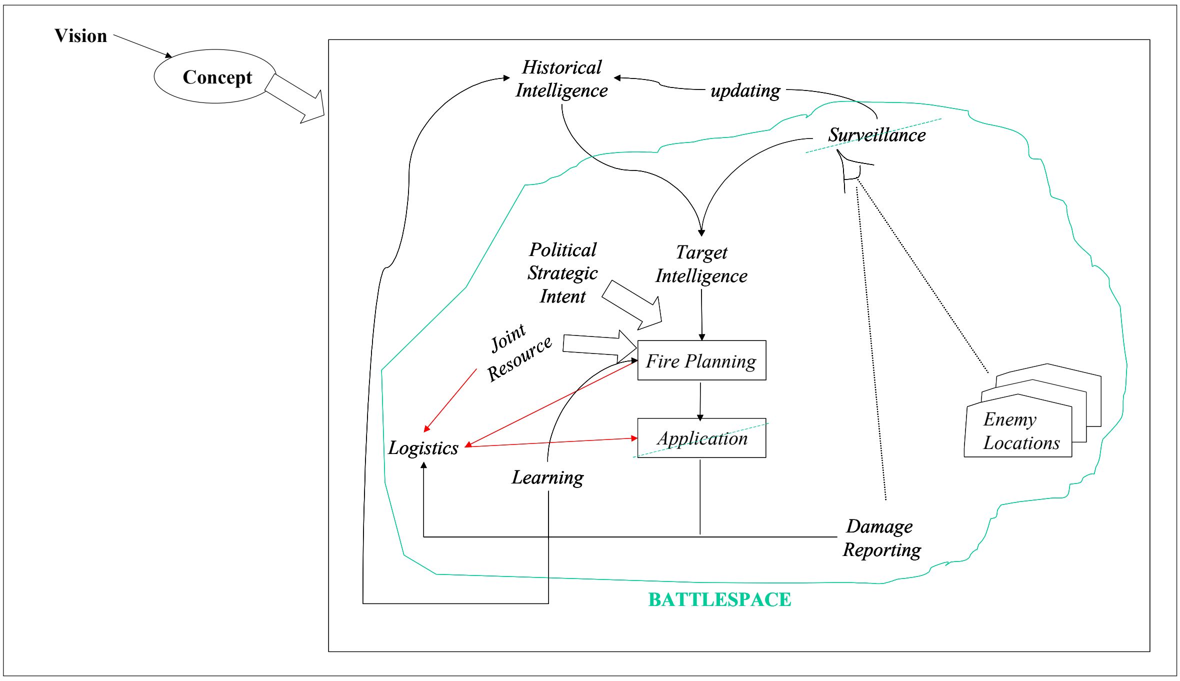

Figure 6: Conceptual Template.

The conceptual template is a generic, graphical representation of JFS and consists of its core internal and external processes and sub-systems. The conceptual template has been used to guide and capture the thoughts of specific stakeholders and assisted in focussing the information gathering and initial analysis. Moreover, it assisted in clearly defining the JFS boundaries and scope of the modelling activities. A plethora of information was available through visionary documents, study reports, Concept of Use documents, National, NATO and US joint and single service doctrines and tactical publications.

From the conceptual template, a Rich Picture (see Figure 7) and Root Definitions were created as consensual representations of processes relevant to JFS. It is noted that although these are the views of the analysts the stakeholders in particular and users' views have been accommodated and have been involved in the validation.

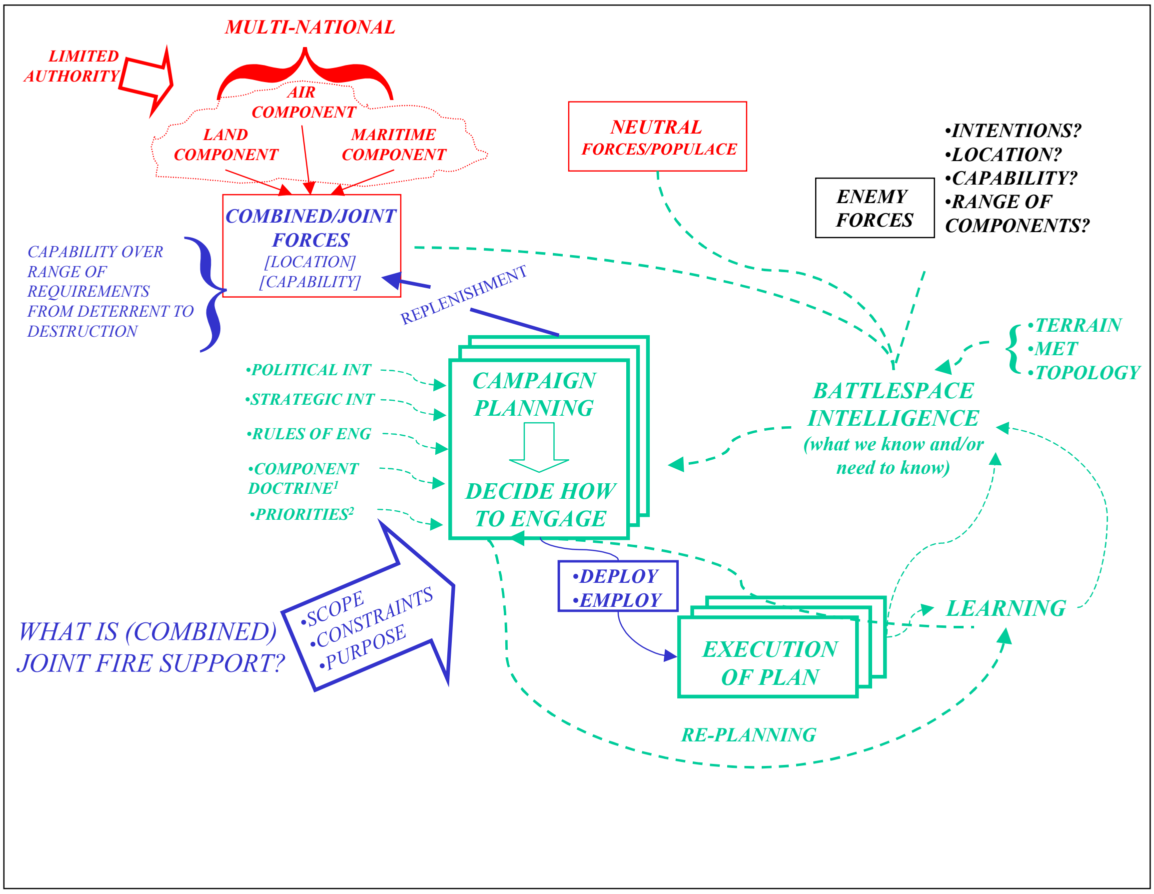

Figure 7: The Rich Picture.

The Rich Picture and the Root Definitions were then used to develop a conceptual model. In order to aid comparison with the AAM it was decided to keep the model larger in scope than JFS. The level 1 processes of this model and level 2 and level 3 examples are shown in Figure 8 below.

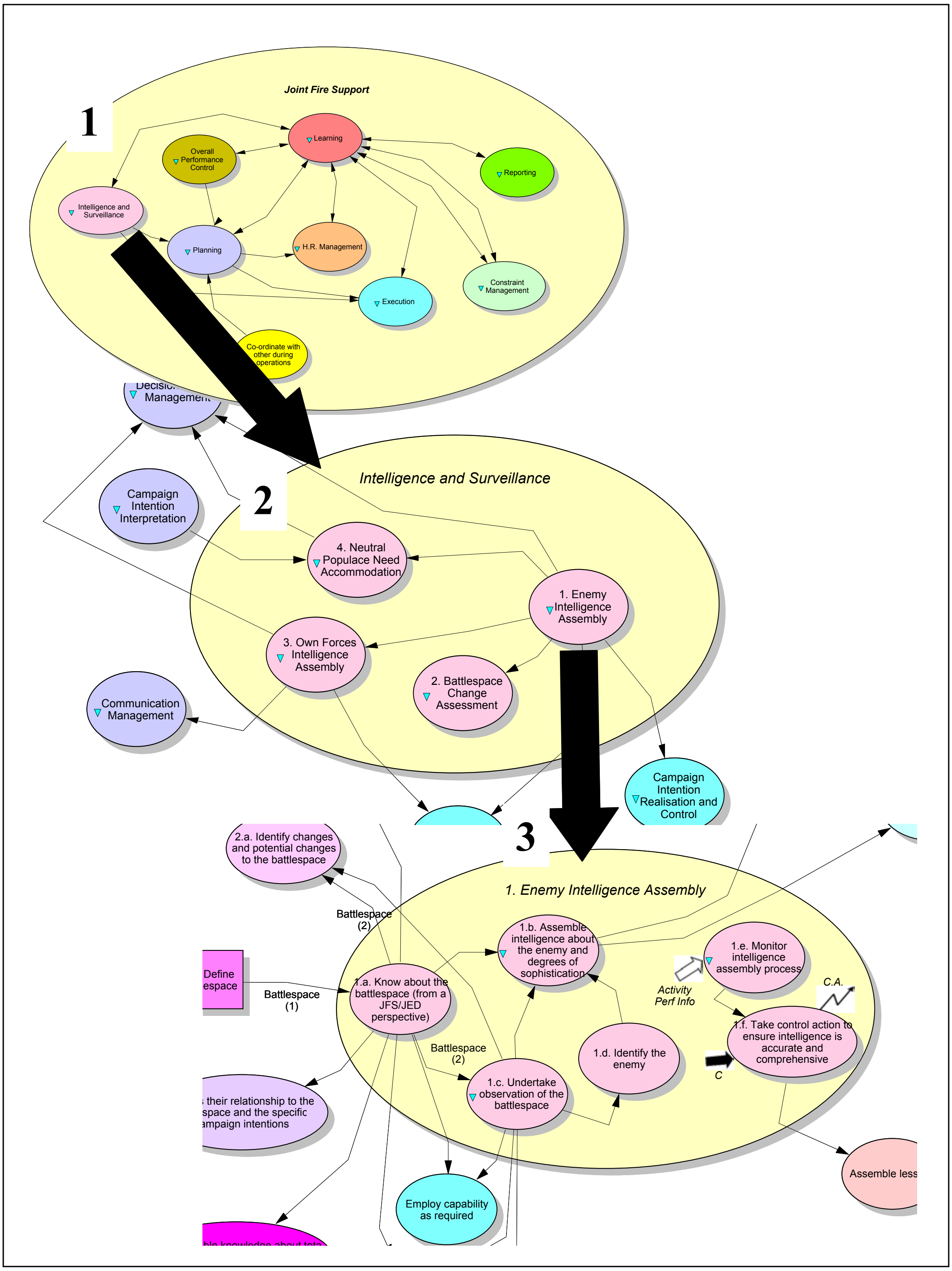

Figure 8: JFS CM Level 1, 2 and 3 Processes.

This conceptual model was then related to the Army Activity Model (AAM) to identify gaps and overlaps between JFS and the AAM, the latter containing the information detail and information dependencies as explained earlier. It was then possible to determine the degree of relevance of the AAM to JFS processes (see Figure 9).

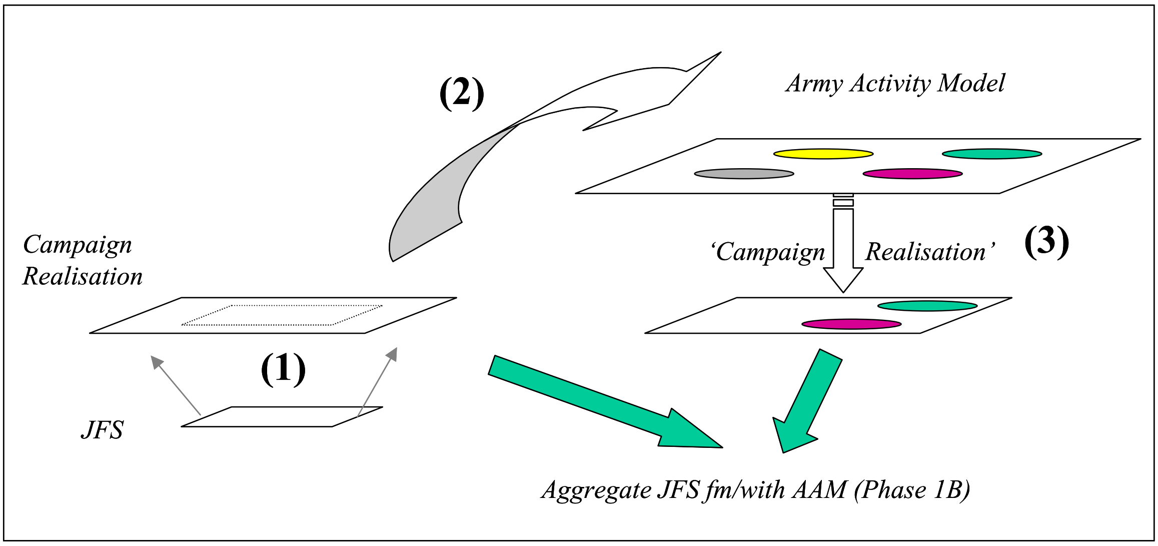

Figure 9: Using the CM to Determine the Appropriate AAM Processes.

Having followed this approach, a defensible and coherent JFS conceptual process model or aggregate model could be developed. Moreover, there was a perceived risk – as became apparent during the development of the application coherence assessment method – that certain processes in the AAM were themselves not coherently defined. Therefore it was decided that the intellectual process associated with the modelling activity had to take place independently of the AAM. Hence, this would mitigate the risk of incoherency caused by using inappropriate conceptual representations in the AAM. As a result of contrasting the generic/conceptual model with the AAM, future activities concerning the improvement of the AAM could also be identified. The AAM and the conceptual model were then combined to develop an enhanced process model relevant to JFS, which is available to for amendment and updating of the AAM.

The relationship between the various stages (Stage 1A, 1B and 2) is depicted in the Figure 10 below. Stage 1A focussed on the development of the conceptual model for JFS, whereas Stage 1B concentrated on using this model to 'filter' the relevant AAM processes and information categories. Subsequently, during Stage 2 the aggregate model of the 'JFS system served' was used to develop a JFS BISA or 'serving system' model. In collaboration with requirements staff and operational users those processes of the aggregate model were identified which would require automation (or IT support). Throughout the modelling activity, the project office has independently of the modelling activity together with the potential users developed a first version of a user requirements document. As will be explained below, following the application coherence method the conceptual and aggregate models could be used to validate these requirements.

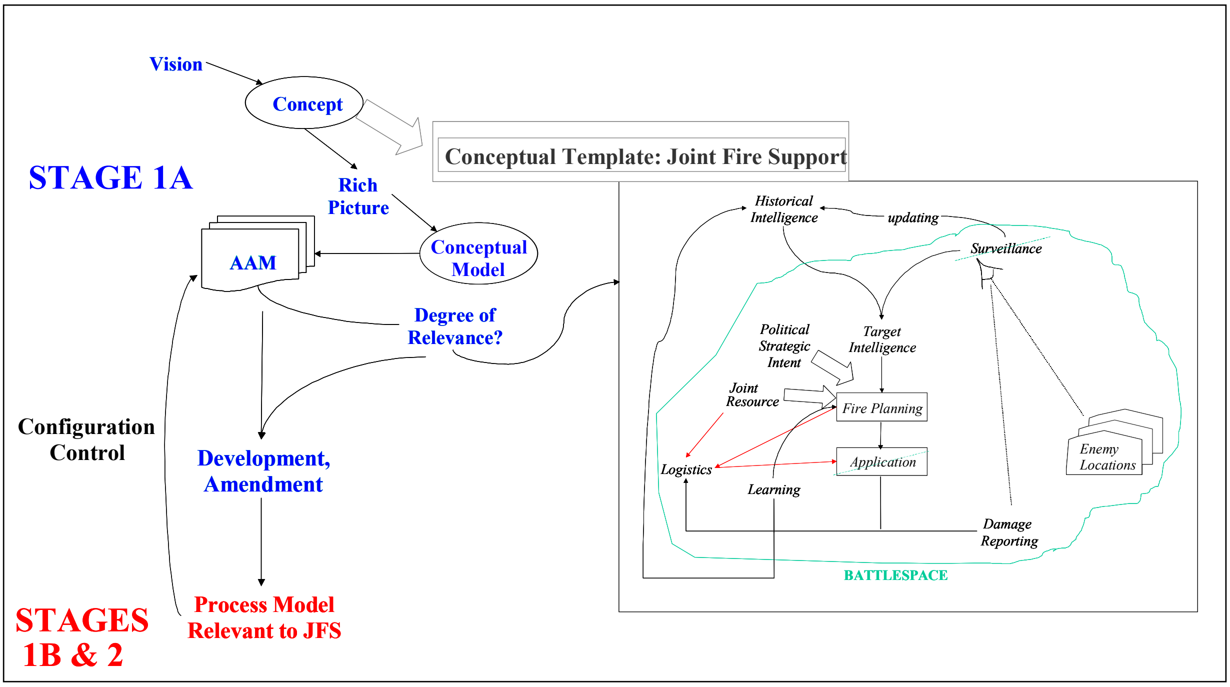

Figure 10: Stage 1A, 1B and 2 Activities.

4.2 Application Coherence and User Requirements Validation

The JFS example illustrates how the principles of the application coherence method could be used for the early stages of system design. Firstly, activities concentrated on defining 'what' JFS was taken to be, and its coherent definition was ensured through the use of the Army Activity Model. Secondly, based on the answers to the 'what-question', i.e. the definition of the served system, it was determined 'how' this system will be supported by an Information System, i.e. the serving system. Although, ideally URs should be based on the process and information needs of the Army as captured in the business model, i.e. the AAM, for the UK Army's digitisation programme or the business area related conceptual model, as for JFS, often this does not occur. Because the AAM had not been developed for it to be available in time, problems now exist to assess whether the current set of URs support a coherent system development. Often much effort has been expanded in formulating those requirements by involving potential users and it would not be prudent to discard their views and experience.

At the higher level of the entire digitisation programme, the problem is particularly complex as different facets are described using different language (conceptual, real world). It is very likely that the URs, although structured are not coherent[5]. Moreover, the digitisation programme has not been underpinned by a set of logical models which has now become available through the development of AAM, preparation for application coherence assessment, et al. Consequently, URs have been specified without logical structure and defensible scope. Finally, there are no agreed definitions of scope and capability for the various business areas which could serve as a high-level structure for all URs.

To ensure that development of the IS occurs coherently while meeting the URs, the URs should reflect the Army's new business processes, which are found in the AAM or extensions to it. In principle, it is possible to identify the set of activities in the AAM and their information dependencies that represent the

[5] Requirements are grouped into a section for each BISA; Each BISA records requirements using a different structure and to varying degrees on detail/completeness, requirements have not been normalised.

capabilities needed ("what needs to be done") for a given business area. However, it is probable that certain activities of the AAM may have been specified at too high a level to be of immediate use.

As has been explained earlier, mapping of functional areas to appropriate activities in the AAM has occurred. However these types, based on staff functions, bear no resemblance to the business areas used in the structure of existing URs. Consequently, business area boundaries need to be derived rather than immediately mapped. A complimentary view of the capabilities required for the digitisation programme is that provided by the set of URs.

The UK digitisation programme is based on the development of distinct Battlefield Information System Applications (BISAs) to support particular business areas (e.g., JFS BISA), whereas common BISAs will be developed to support those processes which are – more or less – shared Army-wide (e.g., Common Battlefield Application Tool – COMBAT). An important aim of the digitisation programme is that certain BISAs, or their constituent tools (i.e., Battlefield Information System Tools – BISTs) will be available for implementation across the Army business areas, which will prevent duplication of development effort and which in turn should support coherent development. The BISAs and BISTs are defined in a catalogue for which a set of 'functional area' process models has been built during its development. Like the AAM these models, one for each business area, define process and information. The models have been analysed to identify where, in the judgement of the analyst, tools (potential BISTs) may support business processes. Subsequently, BIST definitions are provided based on data flow diagrams of the tool processes. Unfortunately only a few of the business areas completed this analysis. The remainder, through business area subject matter experts, made no distinction between business processes and tool processes to support the appropriate subset of those business processes. Hence, the content of the BISA catalogue is of varying quality. The catalogue does contain a reasonable structure for the set of BISTs. A method has now been developed to improve consistency and coherence across the full range of URs. The method has been based on the applications coherence method described earlier.

In addition to the aforementioned model development process described for JFS (i.e. conceptual model, and aggregate model), analysis now focuses on how URs relate to the processes and information elements of the model. Firstly, the URs needs to be analysed and ambiguities removed after which information elements (IE) are derived for these URs. These IEs are mapped onto or translated into ICs or IP definition as appropriate, so that tools (ICAT[6]) could be used to manipulate information and compare against a coherent reference taxonomy.

Figure 11 shows how for a particular business area, the URs from that business area are then compared with the related activities from three core projects (i.e. COMBAT, Platform and Infrastructure BISAs) by deciding what activities those URs relate to in the "Super BISA[7]" model. The three core projects are likely to have a high degree of relevance to most business areas and the analysis is performed to detect gaps and overlaps with the business area BISA. Any relevance of requirements from other projects is picked up at stage 6 of the method.

[6] The ICAT tool is currently being developed by Hi-Q Systems Ltd and Salamander.

[7] This is merely a term to describe the set of logical activities of a business area requiring BIST support, a number of which may be supported by BISTs from business areas other than the one being analysed.

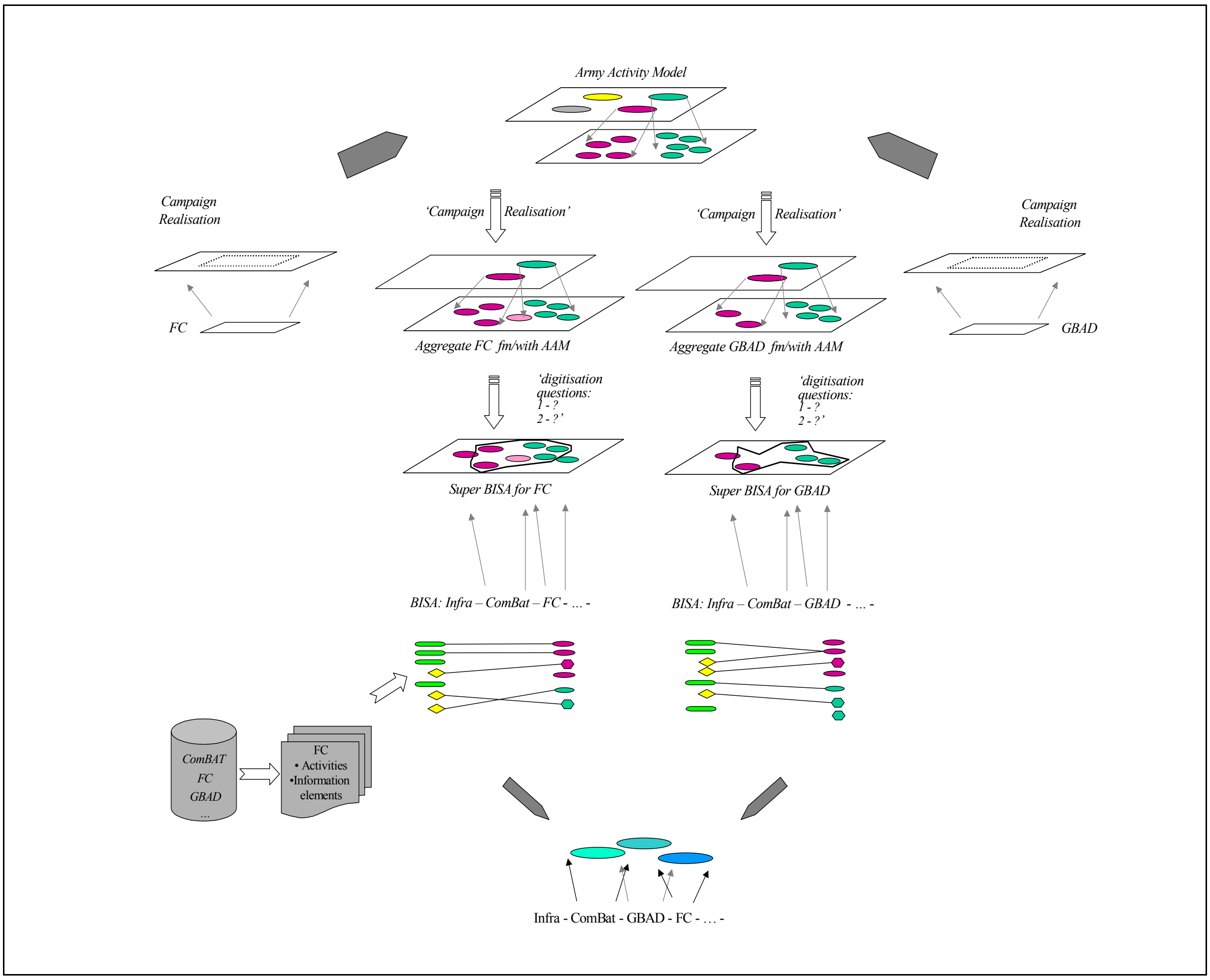

Figure 11: Method.

Further analysis can now be completed and map UR activities and/or information elements to Super BISA activities and information categories. Different Information Products (IPs) for different business areas can map to the same process in the AAM. At lower levels of resolution the same set of IPs may map to different and more specific processes, i.e. those unique to that business area. Care must be taken when undertaking this mapping to ensure that it is done against the aggregate[8] models for the business area and not the AAM itself.

Finally, expert judgement is used to take the automated set of reports for all business areas that shows mappings of URs to "digitisation" activities and identify gaps[9], overlaps, "reasonable" mappings and hence discuss the legitimacy of each UR[10]. This will require an ability to interpret the tool results by categorising most likely associations between URs and AAM activities.

[8] An aggregate view shows all processes and their interactions as a single flat view rather than the set of individual views generated by hierarchical decomposition.

[9] Gaps work in both directions: those URs with no association to models and hence illegitimate and "digitisation" activities in models that have no URs that therefore require URs to be written.

[10] The sort of expert and the criteria for "reasonable" mapping will need to be defined during the follow on project.

Comparison across programmes, e.g., Joint Fire Support BISA, Fire Control BISA and GBAD BISA, will also lead to a better informed, higher level view and assessment of coherent development at an organisational level. A more detailed insight in the overlaps and gaps between programmes can be visualised while the programmes are still in the requirement definition or design phases, and adjustments are likely to be less costly.

5.0 CONCLUSION: APPLICATION COHERENCE AND THE COBP

The NATO COBP highlights that it does not provide guidance on the development and design of new systems. Therefore, the specific use of the application coherence assessment method as addressed in this paper, cannot be contrasted against the COBP. However, as has been explained in this paper current methods still fail to support user needs and do not address information requirements appropriately. The application coherence assessment method overcomes this shortfall. Not only does it support the assessment of the degree to which existing information systems support business processes, but it also enables the development of new systems in a coherent manner.

Many of the information aspects are being addressed during the requirements and design stages of a particular C2 information system programme. Moreover, the candidate system is being assessed in a larger context and hence is being considered as part of the larger information enterprise. In addition to the coherence assessment at informatics level a more technically focussed assessment could be conducted determining the coherency of a new systems as part of the larger system-of-systems with a greater level of detail.

In contrast to many other methods and techniques, the application coherence method embraces human and organisational aspects throughout. Therefore, a more complete foundation has been created on the basis of which subsequent analysis could be conducted, e.g., through more traditional forms of operational analysis as described in the COBP. Moreover, since the application coherence method is information focussed it envisages the creation of an information enterprise that is required to achieve the objectives of information superiority.

It has been illustrated that the application coherence method enables the assessment of the effectiveness of potential systems to commence during their inception rather than upon completion when also the challenges for analysts are disparate and come in large quantities. Moreover, early insight into the degree of potential effectiveness would enable decision-makers to plan alterations and improvements when financial consequences are still minimal and system changes easier to achieve. The application coherence assessment method discussed in this paper does not conflict with the COBP, instead it should be seen as a complimentary method which could take away some of the burden experienced with operational analysis.

6.0 ACKNOWLEDGEMENTS

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7.0 REFERENCES

Aristotle (1992), “The Politics”, translated by Sinclair, T.A. original 1962, 1992 reprint, Penguin Books: London.

Beckner, S.G. (2000), “Information Feasibility: Using the Concept for Planning the Information Needs of Deploying Forces”, MTR 00B0000031 MITRE: Colorado Springs, Co.

CCTA (1993), "Applying Soft Systems Methodology to an SSADM Feasibility Study", HSMO: London.

Checkland, P. and Holwell, S. (1998), "Information, Systems and Information Systems, Making Sense of the Field", John Wiley and Sons: Chichester, New York, Brisbane, Toronto, Singapore.

Checkland, P. and Scholes, J. (1999), "SSM in Action", John Wiley and Sons: Chichester, New York, Brisbane, Toronto, Singapore.

Clausewitz, von C. (1982), Over de Oorlog, original title "Vom Kriege" translated by Hans Hom, Het Wereldvenster: Houten.

Hi-Q Systems Ltd (2001), "A Method for Promoting Application Coherence", a paper for DINF(A), Doc No. C207-EP-01, Iss 1.0b May 2001.

McBeth, M.S. (2000), "Risk Driven Outcome-based Command and Control (C2) Assessment", Space and Naval Warfare Systems Center, Suffolk, VA.

NATO (2002), "Code of Best Practice for Command and Control Assessment (COBP)".

PAM 525-5 (1994), "Force XXI Operations: A Concept for the Evolution of Full Dimensional Operations for the Strategic Army of the Early Twenty-First Century", US Army Training and Doctrine Command (TRADOC), Washington, 1 August.

Rochlin, G. (1997), "Trapped in the Net; the Unanticipated Consequences of Computerisation", Princeton Paperbacks: New Jersey.

't Hart, P. (1993), "Symbols, Rituals and Power: the Lost Dimensions of Crisis Management", Journal of Contingencies and Crisis Management 1(1): 36-50.

Wilson, B. (1990), "Systems: Concepts, Methodologies and Applications", 2nd Edition, John Wiley and Sons: Chichester, New York, Brisbane, Toronto, Singapore.

Worm, (2001: 1), "Integrated Modelling and Analysis of Cognitive Mechanisms in Distributed Command Teams and Command and Control Systems", Paper presented at European Symposium on People in Digitized Command and Control, Royal Military College of Science, Shrivenham (UK), 12-13 December 2001.

8.0 LIST OF ACRONYMS

AAM	Army Activity Model
BISA	Battlefield Information System Application
BIST	Battlefield Information System Tool
C2	Command and Control
C2IS	Command and Control Information System
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CM	Conceptual Model
COBP	Code of Best Practice
COMBAT	Common Battlefield Application Tool
FA	Functional Area

FC	Fire Control
GBAD	Ground Based Air Defence
IC	Information Category
IP	Information Products
IS	Information System
IT	Information Technology
JFS	Joint Fire Support
ORBAT	Order of Battle
RW	Real World
RWA	Real World Activity
SSM	Soft System Methodology
UK	United Kingdom
UR	User Requirements
URD	User Requirements Document

AUTHOR BIOGRAPHY

Kees van Haperen MSc MICDDS MBCI is a Senior Consultant with Hi-Q Systems Ltd specialised in military C2IS and (SSM) process and information modelling. As a former Fighter Controller with the Royal Netherlands Air Force, he has specialised in C2, interoperability and tactical data communications. He has been working in the UK since 1996 and has been involved in the development of national and international operational concepts and procedures, a large number of national and international air force, navy and army platform and system programmes, e.g., NATO ACCS, the Australian Air Defence System Vigilare, German Tiger Helicopter and tactical data link implementations in various UK platforms (TACC, Nimrod, Tornado ADV, GRAP IOC, etc.). In 2000, he completed a Masters degree in Risk, Crisis and Disaster Management, which has enabled him to include the 'softer' aspects of C2, in particular those related to crisis management and team decision-making under stress. More recently, he has been focussing on the development of conceptual models and information architectures in support of several BISAs of the UK Army's digitisation programme. He has published several scientific papers on risk and crisis management and the use of simulation exercises for crisis management.

Analysis of Effects-Based Operations – The Road Ahead to Doing Business Differently

Lieutenant Colonel Ted T. Uchida
AF/XOCW
1911 N. Ft Myer Drive, Suite 1200
Arlington, Virginia 22209
USA
[1] 703-588-2717
ted.uchida@pentagon.af.mil

ABSTRACT

Currently, a significant amount of discussion in the United States Air Force centers on Effects-Based Operations (EBO) as the new way to fight. This debate ranges from Military Operations Research Society (MORS) workshops sponsored by senior civilian and military leaders to articles and booklets written by USAF general officers. This paper will provide a definition and brief discussion of EBO before focusing on its main area – EBO in Wargaming, Experimentation, and Exercises. The EBO in Wargaming, Experimentation, and Exercises section of the paper will address EBO as a concept and process and finally a concept of operations (CONOPS). In addition, it will explore an experimentation strategy for determining the "good" and "bad" aspects of EBO and how to logically progress from Wargames through Experiments to Exercises. In an effort to map the road ahead for analysis of EBO, the paper will address four questions:

1) *How are Effects-Based Operations currently analyzed and/or characterized in wargames, experiments, and exercises?*
2) *What are the indicators of success for Effects-Based Operations in wargames, experiments, and exercises?*
3) *What tools and techniques are available to analyze and measure the indicators of success and do any shortfalls exist in this set of tools and techniques?*
4) *What can be done to improve the analysis of Effects-Based Operations?*

The paper will conclude by highlighting on-going efforts to incorporate and implement Effects-Based Operations in future wargames, experiments, and exercises and potential impacts on doctrine, organization, training, and leadership.

***Key Words**: EBO, Effects-Based Operations, Effects, Analysis, Wargames.*

1.0 INTRODUCTION

Purportedly, Albert Einstein had a sign hanging in his office at Princeton that read, "Not everything that counts can be counted, and not everything that can be counted counts." Whether the sign existed or is more of the folklore surrounding Einstein is unimportant because the sentiment is what is germane.

Paper presented at the RTO SAS Symposium on "Analysis of the Military Effectiveness of Future C2 Concepts and Systems", held at NC3A, The Hague, The Netherlands, 23-25 April 2002, and published in RTO-MP-117.

Reduced to its simplest form, the quote draws a clear distinction between quantitative and qualitative approaches, considerations, and analysis, and concisely makes the point that quantitative efforts alone are insufficient. This distinction and assertion will be especially important and appropriate as we explore the analysis of Effects-Based Operations and, in particular, EBO in wargaming, experimentation, and exercises.

2.0 DEFINITION

Before progressing any further in our discussion, it is important to establish a working definition of Effects-Based Operations. There appears to be myriad definitions for EBO. For instance, in a recent Military Operations Research Society workshop [1], Dr. Paul K. Davis defined EBO as: "Operations conceived and planned in a systems framework that considers the full range of direct, indirect, and cascading effects that may – with different degrees of probability – be achieved by the application of all national instruments: military, diplomatic, economical, and psychological" [2]. Similarly, in their "Analyzing Effects-Based Operations Terms of Reference, MORS put EBO in the context of "A strategic and operational framework for planning, executing, and assessing military operations designed to produce distinctive and desired effects that, in conjunction with other elements of national power such as economic and political actions, compel positive political outcomes. The adaptive application of military, and other capabilities to realize specific, desired operational and strategic outcomes in peace and war in the face of friction, ambiguity, uncertainty, and adaptive adversaries" [3]. The Air Force, in an August 2001 White Paper, defined EBO "as a methodology for planning, executing, and assessing operations designed to attain the effects required to achieve desired national security outcomes" [4]. The final definition we will consider comes from US Joint Forces Command (USJFCOM) J9. In their October 2001 White Paper, the J9 Concepts Department defined EBO as, "a process for obtaining a desired strategic outcome or 'effect' on the enemy through the synergistic and cumulative application of the full range of military and non-military capabilities at all levels of conflict" [5], and further defined an effect as "the physical, functional, or psychological outcome, event or consequence that results from specific military or non-military actions" [6].

All of the aforementioned definitions have several concepts or themes in common. They all consider EBO a system or process that can use military and non-military means or actions to produce synergistic and cumulative effects to influence behavior. Because of these similarities and because we're operating from the orientation of a military organization that very seldom, if ever, acts unilaterally, we will use the USJFCOM definition as our frame of reference and working definition.

3.0 EBO DISCUSSION

As we saw in our discussion of definitions, EBO is variously seen as a system, a methodology, or a process, and this is the best way to think of EBO. It is not a single event, action, or decision point but, rather, a continuous five-stage process, as depicted in Figure 1 [7]. The five stages of the EBO process (Knowledge, Effects, Application, Assessment, and Adaption) fill the inner ellipse in Figure 1 while the arrows in the outer ellipse portray the continuous nature of the EBO process. Arranged around the outer ellipse are the main actions associated with each stage. The process begins with the knowledge stage where one develops comprehensive insight into the adversary or potential adversaries, the environment, and ourselves. In the planning stage one engages in deliberate or contingency planning to achieve the desired effects or outcomes. Once planning is complete, the plan is executed while considering the full range of national capabilities and functions. The assessment phase is where results, in terms of effects and the impact of those effects, are collected, analyzed, and evaluated. This, in turn, leads to the adaptation stage where adjustments or adaptations to the current course of action are made based on effects assessment – all of which are then incorporated into the knowledge stage to continue the process.

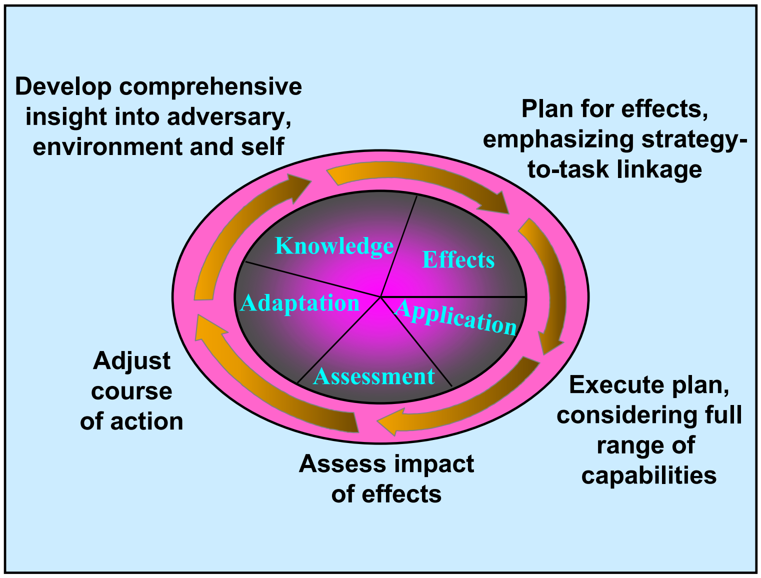

Figure 1: EBO as a Process.

The EBO process is not a new way to fight wars or engage enemies or adversaries, nor is it a replacement for any of the currently recognized or anticipated forms of warfare. As a methodology or process, EBO is a way of thinking and systematically planning, executing, and assessing operations designed to attain specific effects [8] with one of its key strengths being adaptability and incorporation of new concepts and capabilities (Figure 2) [9]. Because one is using a methodology focused on effects rather than means, incorporating new concepts and capabilities is much easier – achieving the desired effect is the focus, not the means.

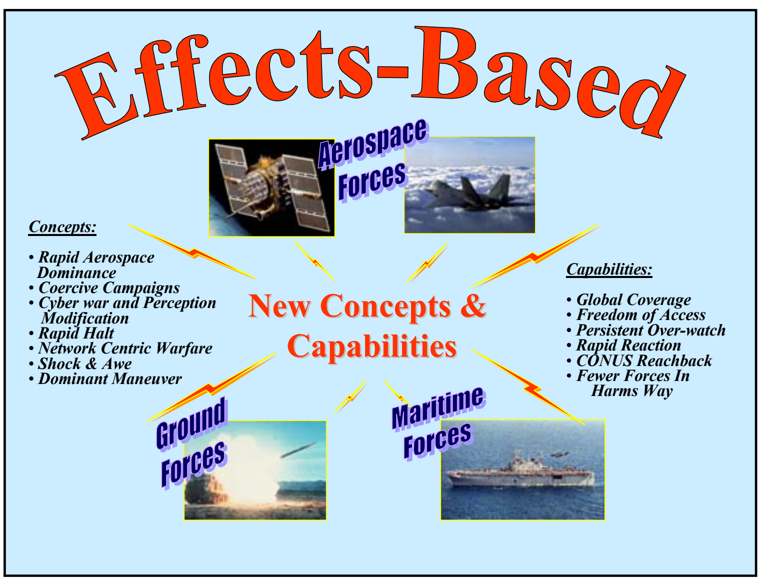

Figure 2: EBO Strength of Incorporating New Concepts and Capabilities.

The second key strength of EBO as a methodology is it improves our ability to use all elements of national power to achieve national policy goals (Figure 3) [10]. Inherent in this strength and coupled with the previously discussed strength is the capability to incorporate tools and elements of national power previously not considered or used. Figure 3 explicitly depicts the Diplomatic, Information, Military, and Economic (DIME) tools while implicitly showing the capability to incorporate other tools by means of the question marks. To take full advantage of the strengths of the EBO methodology, decision-makers must have a clear idea of what it is they are trying to accomplish, what actions might be taken and how the proposed actions will contribute to the desired effect [11].

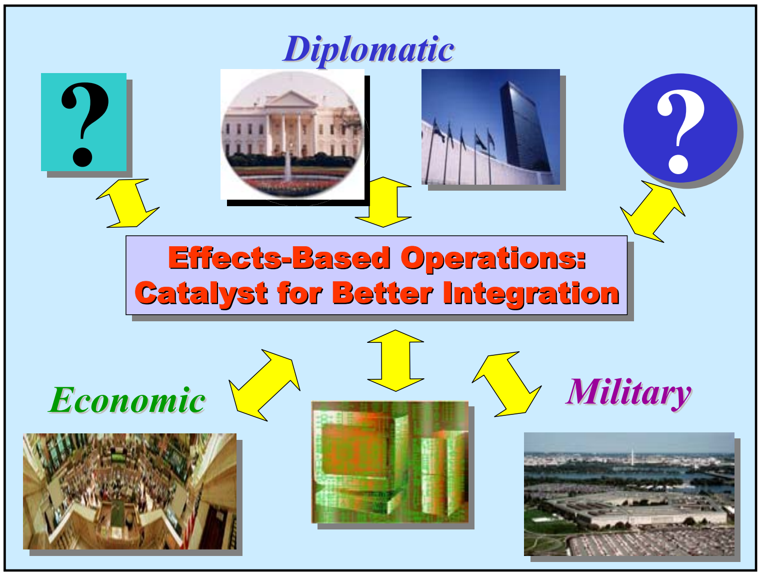

Figure 3: Integration of Tools and Elements.

This discussion was intended to serve as an introduction to the concept of EBO and a brief introduction of EBO as a process and methodology. It should not be considered in-depth, complete, nor exhaustive, but sufficient for understanding what follows.

4.0 EBO IN WARGAMING, EXPERIMENTATION, AND EXERCISES

Now that we have an EBO frame of reference, working definition, and cursory understanding of the concept, it is time to focus on our main area of concern – wargaming, experimentation, and exercises.

For the purposes of our discussion, a wargame is "a simulation, by whatever means, of a military operation involving two or more opposing forces using rules, data, and procedures designed to depict an actual or real life situation" [12]. An experiment is "an operation carried out under controlled conditions in order to discover an unknown effect or law, to test or establish a hypothesis, or to illustrate a known law" [13]. Finally, an exercise is "a military maneuver or simulated wartime operation involving planning, preparation, and execution. It is carried out for the purpose of training and evaluation. It may be a multination, joint, or single-Service exercise depending on participating organizations" [14].

Before we put these definitions to use, however, let's turn our attention to the state of development of EBO.

4.1 EBO as a Concept, Process and Concept of Operations

As noted earlier, EBO as a concept is fairly well understood, discussed, and promulgated, especially throughout the doctrine and analysis communities. Writings by Maj Gen David A. Deptula, Air Combat Command Directorate of Plans and Programs (ACC/XP) and Dr. Paul K. Davis (RAND) have contributed significantly to the understanding of the concept of EBO. However, this is not to propose that a universal common understanding of EBO exists. EBO as a concept, means different things to different people depending on orientation, frame of reference, and intended use. This is one of the strengths of EBO as well as a potential weakness.

Likewise, EBO as a process is developing fairly rapidly and becoming better understood. Writings such as the USJFCOM White Paper, USAF White Paper, and efforts by proponents such as Maj Gen Deptula, Dr. Maris McCrabb (Air Force Research Laboratory) and Mr. Graham Kessler, Joint Forces Command Joint Experimentation (JFCOM J9) have furthered the understanding of EBO as a process. Continued effort is required in the EBO as a process area in order to move to the next level where EBO is an understood and implemented concept of operations with the required tactics, techniques, and procedures for use throughout the community.

EBO as a CONOPS is presently in the beginning stages of development. The JFCOM Joint Experimentation Directorate, which integrates experimentation efforts of all the services and unified commands, has taken the first joint steps toward making EBO a fully developed CONOPS by writing Effects-Based Planning Tactics, Techniques, and Procedures (Final Draft) and Effects Assessment: Joint Tactics, Techniques, and Procedures (Draft). These seminal works have been developed by J9 to facilitate incorporating EBO into Millenium Challenge 02 for experimentation.

As previously stated, we are in the early stages of EBO CONOPS development with much work still ahead for the joint community and individual services. As Maj Gen Deptula said in an Air Force Times article, "Effects-based targeting and operations still have a way to go before they become a standard Air Force practice" [15].

4.2 Experimentation Strategy

EBO has far reaching implications across the range of military operations throughout each service and in joint and coalition operations. As such, there is the potential for experimentation in a variety of venues at every level of operations. Leveraging experimentation events in currently established venues offers lucrative opportunities for understanding and developing EBO as a concept and a process as well as developing the CONOPS [16]. Concept and process experimentation could greatly expand the understanding of EBO. Efforts in interagency relationships, Operational Net Assessment, Effects-to-Task Matrix, Effects Tasking Orders, and alternative headquarters organization structures should be the focus while conducting effects-based processes in the planning, execution, assessment, and adaptation cycle. Limited objective experiments (LOEs) in these areas would increase the understanding of effects related processes.

To provide a common basis of understanding for many of these efforts, initial EBO experimentation should follow a seminar-workshop-wargame/limited objective experimentation sequence. Initially, more can be learned about EBO with narrowly focused events vice events that try to look at the entire cycle of conducting operations that are effects-based. The focus of these events must be scoped down to look at individual areas such as interagency relationships, understanding the adversary, developing effects related Courses of Action (COAs), and assessing actions with an effects-based focus. These activities will provide the venue to further define EBO with insights into potential spiral development of tactics, techniques, and procedures [17]. The organization structures and planning, execution, and assessment processes that emerge from experimentation will help define how EBO will fit into service doctrine and the joint task force of the future [18].

4.3 Progress from Wargames through Experiments to Exercises

Now it is time to use our previously established definitions of wargame, experiment, and exercise. Wargames, while normally depicting actual, projected, or assumed situation, traditionally deal with future concepts and capabilities, i.e., the fuzzy stuff of the future. This is where the concept of EBO would first be manifest in the wargame – experiment – exercise triad.

As the EBO concept is refined and developed into a process, it will move into the experimentation phase. In this phase, joint and service experiments would be used to examine, test, and refine pieces of the EBO process. The goal of experimentation is to examine and test increasingly more pieces of the process until the whole process has been tested. Successful experimentation should result in a CONOPS and associated tactics, techniques, and procedures, which can be promulgated to users in the field by incorporation into doctrine and inclusion in exercises.

To be successful in exercises, EBO must be an integral part of the entire process – planning, executing, and assessing and not an after thought or adjunct. Exercises are designed and conducted to train and evaluate, so we need to fully incorporate EBO as a methodology if we want to maximize our exposure to EBO and our training effectiveness. Familiarity removes fear so the more familiar people are with EBO, the more they will use it.

The key to implementing EBO is to ensure there is a concept, a process, and, eventually, a CONOPS with the required tactics, techniques, and procedures that has progressed from a wargame environment through structured experiments into doctrine and exercises. This progression allows us to keep the good, eliminate the bad, and make refinements throughout the continuum depicted in Figure 4.

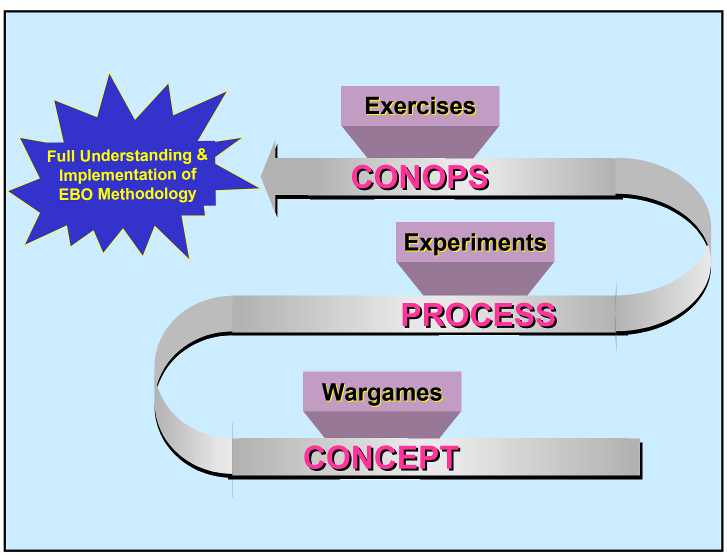

Figure 4: EBO Development and Progression.

5.0 ANALYSIS OF EBO

The analysis of EBO is not as straightforward, clean, or quantitative as attrition-based analysis [19]. When the objective is to change the decisions, actions, and behavior of other actors through coercive means, measures will be primarily systemic, psychological, and sociological rather than physical [20]. In a recent MORS workshop, a working group chaired by Air Force Wargaming and Experimentation Division (AF/XOCW) was tasked to examine how EBO could be characterized in wargaming, experimentation, and exercises. To satisfy their tasking, the group concentrated on the following four questions:

1) How are Effects-Based Operations currently analyzed and/or characterized in wargames, experiments, and exercises?

2) What are the indicators of success for Effects-Based Operations in wargames, experiments, and exercises?

3) What tools and techniques are available to analyze and measure the indicators of success and do any shortfalls exist in this set of tools and techniques?

4) What can be done to improve the analysis of Effects-Based Operations?

5.1 How are Effects-Based Operations Currently Analyzed and/or Characterized in Wargames, Experiments and Exercises?

Figure 5 reflects the discussion areas relating to the first question the working group considered.

How are Effects-Based Operations currently analyzed and/or characterized in wargames, experiments, and exercises?

- **Mil v mil domain modeled reasonably well but what about rest of PMESII?**
  - **Need Multi-disciplinary team**
  - **Currently M & I ok**
  - **Explore other existing models**
- **EBO process: Planning, assessment, feedback, integration**
  - **must be a centerpiece of game design and development**
  - **Currently an add-on**
- **Seminar Games?**
- **Current focus on destruction – need additional/refocus**
  - **Integration with other agency games?**
  - **What about other non destructive applications?**
- **Realistic Red**
  - **Evaluation of perception – Blue/Red; Red/Blue**
  - **Definition of success?**

Figure 5: Current Analysis and Portrayal of EBO.

Currently, we characterize and analyze military operations and the force-on-force (attrition-based action) domain fairly well in wargames, experiments, and exercises. However, when we move outside of the military only realm and attempt to consider relationships between the Diplomatic, Information, Military, and Economic instruments of national power, our characterizations and analysis fall short. The deficiency is more pronounced when we attempt to consider Political, Military, Economic, Social, Infrastructure, and Information (PMESII) relationships and interactions. Although we do military and infrastructure (M & I) fairly well, we need to explore other existing models and embrace a multi-disciplinary approach.

At the present time, EBO is incorporated into our wargames, experiments, and exercises as an add-on. Our efforts, for the most part, are limited to smart people trying to impose an EBO framework on wargames, experiments, and exercises. While improving, we need a more systematic approach and more integration. We need an EBO mindset integrated into the game planning process that frames intent in effects terms. With intent and guidance expressed as effects, Commander's Critical Information Requirements (CCIR) and Intelligence, Surveillance, Reconnaissance (ISR) plans could be developed to produce the metrics required to evaluate effects. As we systematically and consistently include EBO in our wargames and experiments, we must explore the tools required to assist assessment and to evaluate effects so they can be fed back to the participants.

Synthesis is the fundamental concept for EBO and may lead us to using seminar games to address parts and pieces other than the military actions of a game until we find simulations and models for non-military interactions. Preceding military focused wargames with seminar games that address effects planning and contributions of non-military instruments could be very beneficial to all wargame participants.

In our wargames, experiments, and exercises we currently focus on destruction to the exclusion of other tools. To fully embrace EBO, we may need to refocus our efforts or add parts and pieces to fill in the missing models – one that do PMESII well. The single focus on destruction leads to three problems. First, how do we integrate our military focused wargames, experiments, and exercises with other non-military games? Second, how do we consider, incorporate, and assess other non-destructive applications? Finally, how do we present PMESII to decision-makers? These problems are compounded because wargames compress a long time frame into a short period of play and it's hard to capture effects over that short time span. Depending on game objectives, the solution to our problems could be to restructure the venues as well as adding new models.

Another part of our current wargame, experiments, and exercises structure requiring change is our portrayal of the adversary. We must address demographics, cultural, economic, societal, and historical considerations for any adversary we use. We also have to provide the information for participants to get into the head of the adversary which means an in-depth description of the psychology of the enemy leader. The leadership description and other key adversary determinants must be included in game descriptors.

Operational Net Assessment (ONA) will be a key process for both blue and red. ONA is the tool to inform both sides and should form the foundation of their plans. We need to do the up front work to change EBO from merely interesting to compelling.

5.2 What are the Indicators of Success for Effects-Based Operations in Wargames, Experiments, and Exercises?

The primary indicator of success for EBO in wargames, experiments, and exercises is the same as it is in the real world – a change in adversary behavior. Although the primary indicator of success is the same in our artificial environment as it is in the real world, as Figure 6 shows, there are also measurement differences. In our created environments you can freeze the game and examine the causes for an opponent's actions and you can observe the set of behaviors in more detail. In addition, non-military interactions alter with different levels of play. Once hostilities commence, there is little, if any, consideration other than military interactions.

In the real world environment, the tools (DIME) would be cumulative or additive rather than exclusionary. In the wargaming, experimentation, and exercise environment we have better insight into the opponent's plan and perspective as well as the friendly forces commander's perception of the opponent's perspective. In the game, we can ask the respective participant what they were thinking or what they perceived the opponent was thinking.

What are the indicators of success for Effects-Based Operations in wargames, experiments, and exercises?

- Change in adversary behavior
- How are measures different than real world?
  - Can freeze and examine causes for opponent actions
  - Can observe set of behaviors in more detail
  - Interactions (PMSEII – DIME) alter with different levels of play
    - Pre-hostilities to onset of hostilities to post-hostilities
  - Emphasis on opponent's plan & perspective
  - Commander's perception of opponent's perspective
- What are the indicators of effects in Assessment?
  - Add DI & E assessors & players?
  - PMESII interactions
  - Qualitative as well as quantitative
- Measures to show whether effects are being played
  - Process that realistically evaluates effects
  - Are models being used appropriately

Figure 6: Indicators of Success.

Assessing effects in wargames, experiments, and exercises is an area requiring attention and further study. To start correcting this problem, we should add assessors and players with a diplomatic, information, and economic focus to our wargames, experiments, and exercises. We also need to pay special attention to PMESII interactions and preplan both qualitative and quantitative measures of effectiveness.

The main shortfall appears to be in measures that show whether effects are being planned, incorporated, and played in wargames, experiments, and exercises. Again, this is an area that requires more attention and study to find a process that realistically evaluates effects and determines whether models are being used appropriately. As part of the solution to this shortfall, we also need a mechanism for continuously evaluating effects and providing feedback to decision makers on both intended and unintended effects. Was what you planned used? Did what you planned work? Why or why not?

5.3 What Tools and Techniques are Available to Analyze and Measure the Indicators of Success and do any Shortfalls Exist in this Set of Tools and Techniques?

The models and tools, in various stages of development and sophistication, shown under the first bullet in Figure 7 were examined during the workshop. Some of these models and tools have already been used in wargames and experiments with varying degrees of success and acceptance. Several show great promise for further development and incorporation. The bottom line is that both quantitative and qualitative models and tools are being developed to meet the need.

What tools and techniques are available to analyze and measure the indicators of success and do any shortfalls exist in this set of tools and techniques?

- What we've seen
  - Standard analysis tools (Kinetic modeling)
  - TAPS-VSS (decision analysis)
  - Influence Net (Wagenhals/Levis)
  - Nation-State (Bullock)
  - Input/Output model
  - Entropy Based Warfare model
  - Expert discussion
- What's on the horizon
  - Standard Wargaming Toolkit
  - Multi disciplinary / mix of qualitative & quantitative capability
- What we'd like to see
  - Need models of non-destructive processes
  - Use of warfighting decision tools in wargaming
  - Tools to look at decision processes
  - Models that produce output as "plausible distributions"

Figure 7: Tools, Techniques and Shortfalls.

Introduction of the Standard Wargaming Toolkit will provide a forum for presenting and evaluating tools for better integrating and representing EBO in wargames, experiments, and exercises. These too must include a mixture of quantitative and qualitative tools representing a multi-disciplinary approach.

The remaining shortfalls include models that accurately portray non-destructive events such as maneuver, Information Warfare (IW), and diplomatic or economic actions, which are required for the multi-disciplinary approach.

In addition, we'd like to see the use of warfighting decision tools in wargaming as well as the development of decision support tools for real world command centers and their integration into wargaming and experimentation events.

We also need decision process tools and models that produce ranges of solutions rather than point solutions. This would be conducive to giving leaders a range of options rather than "the answer."

5.4 What Can Be Done to Improve the Analysis of Effects-Based Operations?

The near term solutions in Figure 8 (definitions, lexicon, and measures) are among the areas currently under discussion at JFCOM. You can't build the analytic components and have them accepted in the community without common, understood definitions; a common and accepted lexicon; and understood and accepted measures.

What can be done to improve the analysis of Effects-Based Operations?

- Near Term
  - Process
    - Definition
    - Lexicon
    - Measures
  - Then you can build right analytic components
- Long Range
  - Capture ambiguities
  - Develop capabilities to analyze these for traceability
- DOTMLPF
  - Capstone Joint Doctrine
    - Joint Effects Board
  - Blue's Red Cell on Commander's staff
    - JTF / SJFHQ organization and process
  - Educate & Train to EBO thought processes
  - Leadership development
    - Exercises
    - Senior mentors

Figure 8: Recommendations.

The lack of standard definitions, a common lexicon, accepted measures, and understanding of the EBO process hamper progression toward a fully developed CONOPS and implementation of EBO. Because of their focus on training, EBO is not ready to be played in exercises but it must be explored in wargames and moved into and through experiments in a systematic manner with alacrity.

Long term solutions need to be able to capture the ambiguities of effects. Multiple actions can produce a single effect and multiple effects can produce a single action. Additionally, the same action may produce conflicting and contradictory effects. The other long term solution we need is the capability to analyze the causal links by tracing effects back to actions.

The requirement to anticipate, execute, assess, and adapt rapidly to create effects that will achieve national policy goals has significant implications for doctrine, organization, training, materiel, leadership and education, people, and facilities (DOTMLPF) [21]. While all areas are affected, major process improvements probably lie in doctrine, organization, training and in developing leaders with an EBO mindset.

EBO envisions extensive use of existing and anticipated information gathering and processing technologies. Vast amounts of information gathered from a host of sources with varying degrees of technical competence will need to be processed electronically into decision-level-quality knowledge for the commander's use. Military staffs integrated with non-military representation will be required to apply this knowledge with and effects-based mindset as they move through the planning, executing, assessment, and adaptation cycle. This will require new doctrine, tactics, techniques, and procedures and organizational changes [22], some of which are shown in Figure 8.

EBO methodology has important training implications as well. The need to rapidly cycle through anticipatory assessment, planning, execution and effects analysis means Joint Task Force and Component Operations Center personnel, for example, must be very carefully trained for that specific role. Moreover, these personnel must be able to understand the integration of the various roles within the component or functional operations center. To work effectively they must be trained in system (facilities, equipment, and linkages) capabilities and limitations, as well as EBO methodology, prior to experiments, exercises and wargames and real world operations [23].

Implementing EBO methodology will require learning a new mindset from the ground up. Certainly, commanders and planners should be the experts in military art and science. Expertise will have to cross multiple domains, however: military art and science plus politics, socio-economics, culture, finance, psychology, physical science, and diplomacy, to name a few. While the primary focus must remain on military art and science, they will also need to know at least enough about each of the other domains to reach into the various disciplines, find the necessary facts and knowledge, and apply them to actions that will create the desired effects. The military will have grow the right kind of specific and general expertise in future leaders from the moment they enter service through the time they become operational planners until they are ready to be component commanders, joint force commanders and commanders in chief. To consistently instill such a mindset in everyone, all professional military and continuing education must incorporate EBO methodology [24].

6.0 SUMMARY

Although we have addressed EBO from a military perspective (our frame of reference), EBO as a methodology or way of doing business could be as applicable to corporations or non-military organizations as it is to the military. Any organization that depends on, and engages in planning of any kind (near term, contingency, strategic, etc.) could benefit from implementing the EBO methodology.

Commanders, corporate leaders, agency heads, and planners at all levels can apply the EBO methodology to all operations. For the military, this application ranges from peacetime engagement, planning for conflict or contingencies, military operations other than war, smaller scale contingencies all the way up to major theater war. Regardless of who employs the EBO, they must think in an effects-based fashion and follow the disciplined EBO methodology of predictive analysis, course of action development, planning, execution, and effects assessment, while adapting their actions and operations to changes in the environment. Above all, commanders, leaders, decision makers, and planners need to consider the effects to be achieved, the consequences of their actions and the means necessary to assess the efficacy of their actions [25].

7.0 REFERENCES

7.1 Notes

[1] Military Operations Research Society Workshop on Analyzing Effects-Based Operations, 29-31 January 2002, Booz Allen Hamilton, McLean, Virginia.

[2] Paul K. Davis, "Effects-Based Operations (EBO): A Grand Challenge for the Analytical Community", Paper presented at the Military Operations Research Society Workshop on Analyzing Effects-Based Operations, McLean, Virginia, 29-31 January 2002, http://www.mors.org/meetings/ebo/ebo_pres/Davis_files/, slide 4.

[3] Military Operations Research Society, "Workshop on Analyzing Effects-Based Operations Terms of Reference", http://www.mors.org/meetings/ebo/ebo_tor/.

[4] College of Aerospace Doctrine, Research, and Education (CADRE), Effects-Based Joint Operations, Draft USAF White Paper, (Maxwell AFB, AL: Air University, August 2001).

[5] USJFCOM J9 Concepts Department, A Concept Framework for Effects–based Operations, White Paper Version 1.0, (Suffolk, VA: JFCOM, 18 October 2001), ii.

[6] Ibid.

[7] Graham Kessler, "Effects-based Operations", Briefing presented at the Military Operations Research Society Workshop on Analyzing Effects-Based Operations, McLean, Virginia, 29-31 January 2002, http://www.mors.org/meetings/ebo/ebo_pres/Kessler_files/, slide 5.

[8] CADRE, Effects-Based Joint Operations, iii.

[9] Tom Erhard, Lt Col., "Effects-Based Operations: Change in the Nature of Warfare", A briefing presented on behalf of Brig Gen David A. Deptula, slide 22.

[10] Ibid., slide 23.

[11] Institute for Defense Analysis/Joint Advanced Warfighting Program, "New Perspectives on Effects-Based Operations", Draft annotated briefing, (n.p. 22 Mar 2001), 23, 26-27.

[12] Department of Defense, Joint Pub 1-02, Department of Defense Dictionary of Military and Associated Terms, (n.p. 12 April 2001 as amended through 15 October 2001), http://www.dtic.mil/doctrine/jel/doddict, 465.

[13] Merriam-Webster's Collegiate Dictionary, Merriam-Webster OnLine, http://www.m-w.com/cgi-bin/dictionary.

[14] Department of Defense, Joint Pub 1-02, Department of Defense Dictionary of Military and Associated Terms, 155.

[15] Bruce Rolfsen, "Effects-based Operations is New Way to Fight", Air Force Times, 7 May 2001, 27.

[16] USJFCOM J9 Concepts Department, A Concept Framework for Effects–based Operations, 34.

[17] Ibid.

[18] Ibid.

[19] Military Operations Research Society, "Workshop on Analyzing Effects-Based Operations Terms of Reference", http://www.mors.org/meetings/ebo/ebo_tor/.

[20] CADRE, Effects-Based Joint Operations, 12.

[21] Ibid., 14.

[22] USJFCOM J9 Concepts Department, A Concept Framework for Effects–based Operations, Appendix A, 1.

[23] CADRE, Effects-Based Joint Operations, 17.

[24] Ibid., 16-17.

[25] Ibid., 11.

7.2 Selected Bibliography

College of Aerospace Doctrine, Research, and Education (CADRE), Effects-Based Joint Operations, Draft USAF White Paper, Maxwell AFB, AL: Air University, August 2001.

Davis, Paul K., "Effects-Based Operations (EBO): A Grand Challenge for the Analytical Community", Paper presented at the Military Operations Research Society Workshop on Analyzing Effects-Based Operations, McLean, Virginia, 29-31 January 2002.

Department of Defense, Joint Pub 1-02, Department of Defense Dictionary of Military and Associated Terms, 12 April 2001 as amended through 15 October 2001.

Deptula, David A. Brig Gen, Effects-Based Operations: Change in the Nature of Warfare, Arlington, Virginia, Aerospace Education Foundation, February 2001.

Erhard, Tom, Lt Col., "Effects-Based Operations: Change in the Nature of Warfare", A briefing presented on behalf of Brig Gen David A. Deptula.

Institute for Defense Analysis/Joint Advanced Warfighting Program, "New Perspectives on Effects-Based Operations", Draft annotated briefing, 22 Mar 2001.

Jamieson, Perry D., "Lucrative Targets The U.S. Air Force in the Kuwaiti Theater of Operations", Washington D.C., Air Force History and Museums Program, United States Air Force, 2001.

Kessler, Graham, "Effects-based Operations", Briefing presented at the Military Operations Research Society Workshop on Analyzing Effects-Based Operations, McLean, Virginia, 29-31 January 2002.

Mann, Edward C. III, Thunder and Lightning Desert Storm and the Airpower Debates, Maxwell AFB, Alabama, Air University Press, April 1995.

Military Operations Research Society, "Workshop on Analyzing Effects-Based Operations Terms of Reference", http://www.mors.org/meetings/ebo/ebo_tor/.

Merriam-Webster's Collegiate Dictionary, Merriam-Webster OnLine, http://www.m-w.com/cgi-bin/dictionary.

Reynolds, Richard T., Heart of the Storm The Genesis of the Air Campaign against Iraq, Maxwell AFB, Alabama, Air University Press, January 1995.

Rolfsen, Bruce, "Effects-based Operations is New Way to Fight", Air Force Times, 7 May 2001.

USJFCOM J9 Concepts Department, A Concept Framework for Effects–based Operations, White Paper Version 1.0, Suffolk, VA: JFCOM, 18 October 2001.

USJFCOM J9 Concepts Department, Effects-Based Planning Tactics, Techniques, and Procedures (Final Draft), Suffolk, VA: JFCOM, 27 September 2001.

USJFCOM J9 Concepts Department, Effects Assessment: Joint Tactics, Techniques, and Procedures (Draft), Suffolk, VA: JFCOM, 16 November 2001.

8.0 LIST OF ACRONYMS

ACC	Air Combat Command
AF	Air Force
CCIR	Commander's Critical Information Requirement
COA	Course Of Action
CONOPS	Concept Of Operations
DIME	Diplomatic, Information, Military, Economic
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, People, Facilities
EBO	Effects-Based Operations
ISR	Intelligence, Surveillance, Reconnaissance
IW	Information Warfare
LOE	Limited Objective Experiment
M & I	Military and Infrastructure
MORS	Military Operations Research Society
ONA	Operational Net Assessment
PMESII	Political, Military, Economic, Social, Infrastructure, Information
USAF	United States Air Force
USJFCOM	United States Joint Forces Command

AUTHOR BIOGRAPHY

Lt Col Ted T. Uchida is Chief, Joint Wargaming Support Branch, Director Command and Control, Deputy Chief of Staff, Air and Space Operations, Headquarters United States Air Force.

Col Uchida was born in Toppenish, Washington on 30 July 1962. He attended Wapato High School, graduating in 1980. After graduation, he attended Washington State University where he enrolled in the Air Force Reserve Officer Training Corps program. In May 1984, Col Uchida graduated with a Bachelor of Science Degree in Computer Science and was commissioned an Officer in the United States Air Force.

In November 1984, Col Uchida was assigned to Mather Air Force Base as a student in Undergraduate Navigator Training. After graduating in July 1985, he went on to Electronic Warfare Officer Training, where he was a Distinguished Graduate in January 1986. Col Uchida began his career as an F-111 Weapon Systems Officer at Mountain Home Air Force Base.

Col Uchida's various F-111 assignments include Assistant Flight Commander and Chief of the Tactics Branch, 20th Tactical Fighter Wing, Royal Air Force Station, Upper Heyford, England; Chief of the Weapons Division, Wing Tactical Deception Officer, Chief of Radar Strike, Flight Commander and Deputy Director, Wing Quality Center, 27th Fighter Wing, Cannon Air Force Base, New Mexico. In June 1996, Col Uchida was assigned as a student, Army Command and General Staff College and School of Advanced Military Studies. Following this assignment he was assigned to Combined Force Command, United States Forces Korea, Republic of Korea as a Combined and Joint Operations Plans Officer, Assistant Chief of Staff, CJ3. Col Uchida assumed his current duty as Chief, Joint Wargaming Support Branch, Deputy Chief of Staff Air and Space Operations on 24 July 2000.

Col Uchida is a graduate of the United States Air Force Weapons Instructor Course, Squadron Officer School, Army Command and General Staff College, and Army School of Advanced Military Studies. He holds a Master of Business Administration from Eastern New Mexico University and Master of Military Arts and Science from Army Command and General Staff College. His awards and decorations include the Defense Meritorious Service Medal, Air Force Meritorious Service Medal, Air Medal, Air Force Commendation Medal, Aerial Achievement Medal, Defense Achievement Medal, and Air Force Achievement Medal. Col Uchida is a Reserve Officer Training Corps and Undergraduate Electronic Warfare Training Course Distinguished Graduate, and Eighth Air Force Tactical Deception Officer of the Year for 1993.

He is married to the former Denise Ann Danforth.

Future Directions

Dr. David S. Alberts
OSD/C3I
Pentagon 3E172
Washington, DC
UNITED STATES

david.alberts@osd.pentagon.mil

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Paper presented at the RTO SAS Symposium on "Analysis of the Military Effectiveness of Future C2 Concepts and Systems", held at NC3A, The Hague, The Netherlands, 23-25 April 2002, and published in RTO-MP-117.

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Annex 1 – LIST OF PARTICIPANTS

SAS -039
23-25 April 2002

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Alberts	Dr.	D.	OSD/C3I	Pentagon 3E172 Washington DC USA	david.alberts@osd.pentagon.mil	+1 703 695 7183	+1 703 614 8060
Allibon	Cdr.	M.C.	UK MOD	DJW-CBM, Room 808 St. Giles Court 1-13 St. Giles High Street London WC2H 8LD UK	djw-cbmcomddev@defence.mod.uk	+44 207 218 6551	+44 207 218 7833
Bailey	Mr.	P.W.	DSTL	DSTL Analysis Farnborough Hampshire GU14 0HF UK	Pwbailey@dstl.gov.uk	+44 1 252 455304	+44 1 252 455062
Bailey	Mr.	R.J.M.	SCS	Systems Consultants Services Ltd. The Court Hourse Northfield End Henley-on-Thames OXON RG9 2JN UK	rbailey@scs-ltd.co.uk	+44 1491 412 102	+44 1491 412 082
Barbier	Mr.	R.R.	TNO-FEL	P.O. Box 96864 2509 JG The Hague THE NETHERLANDS	barbier@fel.tno.nl	+31 70 3740115	+31 70 374 0642
Barfoot	Mr.	R.	NC3A	IPT1 8 Rue de Geneve B 1140 Brussels BELGIUM		+32 2 707 8282	+32 2 707 8770

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Beckers	Mr.	J.	TNO-FEL	TNO Physics and Electronics Laboratory P.O. Box 96864 2509 JG The Hague THE NETHERLANDS	j.j.beckers@fel.tno.nl	+ 31 70 374 0260	+31 70 374 0652
Bella	Mr.	L.	NC3A	CISD P.O. Box 174 2501 CD The Hague THE NETHERLANDS	luigi.bella@nc3a.nato.int	+31 70 374 3042	
Belyavin	Dr.	A.J.	QINETIQ	A50 Building Cody Technology Park Ively Road Farnborough Hants GU14 OLX UK	ajbelyavin@qinetiq.com	+44 1 252 393401	+44 1 252 392097
Boers	BGen.	G.F.M.A.	NL MOD	Landmacht Postbox 90711 2509 CS The Hague THE NETHERLANDS	gfma.boers@mindef.nl	+31 70 316 7511	+31 70 316 7062
Boulet	Mr.	J.L.	PLEXSYS	Interface Products Inc. Joint Interoperability Division US Army Forces Command Fort McPherson, GA 30330-1094 USA	bouletj@forscom.army.mil	+1 404 464 4511	+1 404 464 3151
Brady	Mr.	E.C.	Strategic Perspectives Inc.	1488 Evans Farm Drive McLean, VA 22101 USA	bradyspi@worldnet.att.net	+1 703 748 9660	+1 703 748 9679
Buck	Ltc.	W.J.	SACLANT	7857 Blandy Road Suite 100 Norfolk, VA 23551-2490 USA	buck@saclant.nato.int	+1 757 445 3502	+1 757 445 3242

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Campbell	Mr.	I.	DSTL	DSTL Analysis Farnborough Hampshire GU14 0HF UK	lmcampbell@dstl.gov.uk	+44 1252 455 708	+44 1252 455062
Candan	Dr.	U.	NC3A	Postbox 174 2501 CD The Hague THE NETHERLANDS	umit.candan@nc3a.nato.int	+31 70 374 3602	+31 70 374 3069
Carhart	Lt.Col.	K.R.	RHQ AFNORTH	Post Box 270 6440 AG Brunssum THE NETHERLANDS	AFN J5J9 Carhart K. OF4	+31 45 526 2327	+31 45 563 2343
Charton	Cdr.	P.	NC3A	P.O. Box 174 2501 CD The Hague THE NETHERLANDS	philippe.charton@nc3a.nato.int	+31 70 374 3855	+31 70 374 3239
Chauhan	Mr.	J.	DSTL	Building Q10, Room 21 DSTL Fort Halstead Sevenoaks Kent TN14 7BP UK	jchauhan@dstl.gov.uk	+44 1959 892909	+44 1959 892504
Christie	Ms.	C.	Evidence Based Research Inc.	1595 Spring Hill Road Suite 250 Vienna, VA 22182-2216 USA	Christie@ebrinc.com	+1 703 287 0310	+1 703 821 7742
Cinge	Capt.	M.	TU General Staff	Genelkurmay Harekat Baskanligi Komuta Kantrol Daire Baskanligi Bakanliklar, Ankara TURKEY	mcinge@tsk.mil.tr	+90 312 402 2568	+90 312 417 7614

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Collins	Ms.	M.L.	NC3A	US NATEX 8 Rue de Geneve B-1140 Brussels BELGIUM	collinsm@eur.disa.mil	+32 2 707 8371	+32 2 705 2912
D'Huy	Drs.	C.W.	TNO/FEL	Oude Waalsdorperweg 63 P.O. Box 96864 2509 JG The Hague THE NETHERLANDS	Dhuy@fel.tno.nl	+31 70 374 0021	+31 70 374 0652
Dompke	Dr.	U.	NC3A	P.O. Box 174 2501 CD The Hague THE NETHERLANDS	Uwe.Dompke@nc3a.nato.int	+31 70 374 3636	+31 70 374 3069
Dulger	Lt.	I.	Turkish Air Force	Hv.K.K.Kurmay Bsk.ligi Bilkardes S. Md.lugu 06100 Bakanliklar, Ankara TURKEY	idulger@hvkk.tsk.mil.tr	+90 312 414 3896	+90 312 414 3856
Edwards	Dr.	R.J.	UK MOD	Room 813 Northumberland House Northumberland Avenue London SW2 UK	dfedwards@btinternet.com	+44 207 218 5800	+44 207 218 1799
Eggar	Ltc.	R.N.M	UK MOD	DGD+D Bldg 370 Trenchard Lines Upavon, Pewsey Wilts SN9 6BE UK		+44 1980 615144	+44 1980 615304
Eilertsen	Maj.	O.	RHQ AFNORTH	Postbus 270 6440 AG Brunssum THE NETHERLANDS	AFN J3J7 EILERTSEN O.OF3	045 526 3056	045 526 2697

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Engelhart	Col.	P.J.	LANDMACHT	Prinses Juliana Kazerne Theresiastraat 15 2597 XK The Hague THE NETHERLANDS	las_bo_civ@army.dnet.mindef.	070 316 7465	070-316 7600
Erbetta	Mr.	J.	DSTL	Defence Science and Technology Laboratory, NX6 Malvern Technology Centre St. Andrews Road, Malvern WORCS WR14 3PS UK	jherbetta@dstl.gov.uk	+44 1684 771186	+44 1684 771206
Ercetin	Ltc.	A.	TU General Staff	Genelkumay BILKARDEM Baskanligi Bakanliklar, Ankara TURKEY	a_ercetin@hotmail.com	+90 312 402 3822	+90 312 425 2465
Fidock	Mr.	J.J.T.	DSTL	Portsdown West Portsdown Hill Road, Fareham Hampshire PO17 6AD UK	jfidock@dstl.gov.uk	+44 2392 217699	+44 2392 217791
Flavell	Mr.	R.C.	NC3A	UK NATEX 8 Rue de Geneve B-1140 Brussels BELGIUM	rob.flavell@nc3a.nato.int	+32 2 707 8248	+32 2 707 8770
Friman	Dr.	H.	Swedish National Defence College	P.O. Box 27805 115 93 Stockholm SWEDEN	henrik.friman@swipnet.se	+46 8 788 9343	+46 8 788 9454
Gadsden	Mrs.	J.A.	DSTL	C 138 East Court Portsdown West Portsdown Hill Road Fareham, Hampshire PO17 6AD UK	jagadsden@dstl.gov.uk	+44 23 9221 7696	+44 23 9221 7789

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Gammaitomi	Dr.	L.	AMS - Land Systems	Via Tiburtina KM 12,400 00131 Rome ITALY	lgammaitoni@amsjv.it	+39 06 4150 3650	+39 06 4150 2694
Gerst	Mme.	N.	Interpreter	74 rue du Chateau d'eau 75010 Paris FRANCE		+33 1 448 30264	+33 1 448 30264
Gibson	Dr.	C.	UK MOD	DSTL Portsdown West Portsdown Hill Rd Fareham UK		+44 2 392217686	+44 2 392 217789
Grosu	Lt.Cdr.	C.	NATO HQ	Romanian Mission B-1110 Brussels BELGIUM	romania.milrep@hq.nato.int	+32 2 707 2712	+32 2 707 2710
Hartley III	Dr.	D.	Hartley Consulting	106 Windsong Ln Oak Ridge, TN 37830 USA	DSHartley3@comcast.net	+1 865 482 3268	
Hayes	Dr.	R.	Evidence Based Research Inc.	1595 Spring Hill Road Suite 250 Vienna, VA 22182-2216 USA	rehayes@ebrinc.com	+1 703 893 6800	
Helliker	Mr.	M.	DSTL	Building Q10, Fort Halstead Sevenoaks, Kent TN14 7BP UK	mark.Helliker@dstl.gov.uk	+44 1959 892906	+44 1959 892504
Hinchliff	Mr	N.	BAE Systems	W392(B) Warton Aerodrome Warton, Nr. Preston Lancs PR4 1AX UK	noel.hinchliff@baesystems.co	+44 1772 852513	+44 1772 855449

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Horne	Dr.	G.	MITRE	Marine Corps Combat Development Command 3300 Russell Road (C45) Quantico, VA 22134-5130 USA	gehorne@mitre.org	+1 703 580 0077	+1 703 580 0597
Houles	Dr.	A.	NC3A	CCSD P.O. Box 174 2501 CD The Hague THE NETHERLANDS	alain.houles@nc3a.nato.int	+31 70 374 3078	+31 70 374 30798
Huber	Prof.	R.K.	University of Fed. Armed Forces	Werner-Heisenberg-Weg 39 D 8877 Neubiberg GERMANY	huber@informatik.unibw-muenchen.de	+49 89 6004 2206	+49 89 6004 3036
Hunt	Ltc.	C.W.	US Army CID	8652 Morning Star Ct. Springfield, VA 22153 USA	huntc@belvoir.army.mil	+1 703 805 3528	+1 703 805 2351
Iscioglu	Ms.	P.O.	NC3A	P.O. Box 174 2501 CD The Hague THE NETHERLANDS		+31 70 374 3616	+31 70 374 3069
Janosec	Dr.	J.		Inst. Strat. Studies of Miliary Academy in Brno Kounicova 44 612 00 Brno	josef.janosec@vabo.cz	+420 5 4118 3680	+420 5 4118 3371
Keith	Mr.	R.	NC3A	P.O. Box 174 2501 CD The Hague THE NETHERLANDS	bob.keith@nc3a.nato.int	+31 70 374 3794	+31 70 374 3079
Korte-Möhlenkamp	Ltc.	J.	NC3A	Postbus 174 2501 CD The Hague THE NETHERLANDS	johannes.korte-moehlenkamp@ nc3a.nato.int	+31 70 374 3874	

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Kroening	Mr.	D.	TRAC-FLVN	255 Sedgwick Ave Fort Leavenworth Kansas 66027-2345 USA	kroenind@trac.army.mil	+1 913 684 3330	+1 913 684 9109
Kurik	Ing.	J.	VTUE Praha	Military Technical Institute of Electronics Pod Vodovodem 2 158 00 Prague 5 CZECH REPUBLIC	jkurik@vtue.cz	+420 2 20207701	+420 2 2020 7810
Lambert	Mr.	N.J.	NC3A	AC3IA Branch ORFSD P O Box 174 2500 CD The Hague THE NETHERLANDS	nicholas.lambert@nc3a.nato.int	+31 70 374 3603	+31 70 374 3069
Lascar	Mr.	G.	DGA/CAD	16 bis avenue Prieur de la Cote d'Or 94114 ARCUEIL Cedex FRANCE	georges.lascar@cad.etca.fr	+33 1 42 31 9129	+33 1 4231 9024
Le Grand	Col.	N.P.	TNO-FEL	P.O. Box 96864 2509 JG The Hague THE NETHERLANDS	grand@fel.tno.nl	+31 70 374 0049	+31 70 374 0652
Main	Mme.	J.	Interpreter	152 rue Saint Charles 75015 Paris FRANCE		+33 1 4557 8045	+33 1 4557 6413
Mathieson	Mr.	G.	DSTL	C134, East Court, DSTL Portchester Hill Road Fareham, Hampshire PO17 6AD UK	Glmathieson@dstl.gov.uk	+44 239 217732	+44 2392 217791
Mazaud	Mme.	M-C.	Interpreter	70 rue de Paris 92100 Boulogne FRANCE		+33 1460 41171	+33 1482 52568

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Meiler	Mr.	P.P.	TNO-FEL	P.O. Box 96864 2509 JG The Hague THE NETHERLANDS	meiler@fel.tno.nl	+31 70 374 0234	
Mikolaschek	Mr.	A.	NC3A	P.O. Box 174 2501 CD The Hague THE NETHERLANDS	alfred.mikolaschek@nc3.nato.in	+31 70 374 3080	+31 70 374 3079
Mitchell	Dr.	R.E.	CA DND	Operational Research Division MGen George R. Pearkes Bldg Ottawa, Ontario K1A 0K2 CANADA	mitchell@ora.dnd.ca	+1 613 992 3206	+1 613 992 3342
Moffat	Prof.	J.	DSTL	Defence Science & Technology Lab. DSTL, A3 Building Farnborough GU14 OLX UK	jmoffat@dstl.gov.uk	+44 1 252 455374	+44 1 252 455062
Murashige	Mr.	A.	HQ USAF/XOC-S	Senior US Rep, NATO RTO SAS Panel 1480 AF Pentagon Washington DC 20330 USA	Allen.murashige@pentagon.af.mil	+1 703 588 5050	+1 703 588 8099
Nasrullah	Mr.	M.	NC3A	NL NATEX 8 Rue de Geneve B-1140 Brussels BELGIUM		+32 2 707 8214	+32 2 707 8770
Ng	Dr.	K.	CA DND	Operational Research Division 101 Colonel By Drive Ottawa, Ontario K1A 0K2 CANADA	kevinng@ora.dnd.ca	+1 613 992 9894	+1 613 992 3342
Noble	Dr.	D.	Evidence Based Research Inc.	Suite 250 Vienna, VA 22182 USA	noble@ebrinc.com	+1 703 287 0312	+1 703 821 7742

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Payan	Mr.	F.	Independent Consultant Titan Corp.	663 Las Granjas Drive El Paso, Texas 79932-2300 USA		+1 915 584 5004	+1 915 845 1747
Pearce	Mr.	P.V.	DSTL	Building Q10 Fort Halstead, Sevenoaks Kent TN14 7BP UK	pvpearce@dstl.gov.uk	+44 1959 892087	+44 1959 892504
Pickburn	Mr.	G.A.	Defence Science & Technology Laboratory	C134 Grenville Building Portsdown West, DSTL Fareham, Portsmouth PO 17 6AD UK	gapickburn@dstl.gov.uk	+44 2 392 217723	+44 2392217791
Pille	Mr.	V.	DREV/DND	2459 boul Pie XI North Val Belair Quebec G3J 1X5 CANADA	valdur.pille@drev.dnd.ca	+1 418 84 44000 x4457	+1 418 8444 538
Rech	Mr.	J.R.	IABG	Einsteinstr. 20 D 85521 Ottobrunn GERMANY	rech@iabg.de	+49 89 6088 2587	+49 89 6088 3382
Santangelo	Mr.	F.	IT Navy Procurement Agency	Piazzale Della Marina 4 00100 Roma ITALY		+39 06 3680 4169	+39 06 3680 4558
Simonsen	Mr.	K.J.	DDRE	Ryvangs Alle 1 P.O. Box 2715 DK 2100 Copenhage Ø DENMARK	kjs@ddre.dk	+45 3915 1779	+45 3929 1533
Sinclair	Mr.	R.	VERIDIAN	Information Solutions Division 2101 Executive Drive Tower Box 51 Hampton, VA 23666 USA	mark.sinclair@veridian.com	+1 757 825 4097	+1 757 825 7382

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Sinden	Dr.	A.	UK MOD	Director (Scrutiny and Analysis) Sea/CIS Room 115 Northumberland House Northumberland Ave London WC2N 5BP UK	Tsinden.dgrt@gnet.gov.uk	+44 207 218 7796	+44 207 218 5129
Smeenk	Dr.	B.J.E	TNO-FEL	Postbus 96864 2509 JG The Hague THE NETHERLANDS	smeenk@fel.tno.nl	+31 70 374 0161	+31 70 374 0642
Smith	Mr.	L.	NC3A	P.O. Box 174 2501 CD The Hague THE NETHERLANDS	laurent.smith@nc3a.nato.int	+31 70 374 3796	+31 70 374 3079
Snajder	Mr.	M.	VTUE Praha	Military Technical Institute of Electronics Pod Vodovodem 2 158 00 Prague 5 CZECH REPUBLIC	jkurik@vtue.cz	+1 420 2 2020 7731	+1 420 2 5162 3397
Soldaat	Maj.	P.	RNLA	Support Centre Ede THE NETHERLANDS			
Sowa	Col.	A.	NATO HQ, IMS	Office AA 142 B-1110 Brussels BELGIUM	lar.R&T@hq.nato.int (Col. Sowa)	+32 2 707 5360	+32 2 707 9869
Spaans	Mr.	M.	TNO-FEL	TNO Physics and Electronics Laboratory P.O. Box 96864 2509 JG The Hague THE NETHERLANDS	Spaans@fel.tno.nl	+31 70 374 0211	+31 70 374 0652

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Starr	Mr.	S.	MITRE	7515 Colshire Drive MS N650 McLean, VA 22102-7508 USA	starr@mitre.org	+1 703 883 6432	+1 703 883 6767
Stoop	Mr.	S.	Univ. of Twente	P.O. Box 217 7500 AC Enschede THE NETHERLANDS	s.g.c.stoop@wmw.utwente.nl	+31 53 489 4132	
Striek	MGen.	P.J.E.J.	RNL A	C2 Support Centre Elias Beekman Kazerne Nieuwe Kazernelaan 10 6710 Ede THE NETHERLANDS		+31 318 683220	
Titze	Ltc.	K.	ASTudÜbw/OR	Werner-Heisenberg-Weg 39 85577 Neubiberg GERMANY	klaustitze@bwb.org Klaus.Titze@T-Online.de	+49 89 6004 4120	+49 89 6004 410
Tolk	Dr.	A.	VMASC	7000 College Drive Suffolk, VA 23435 USA	atolk@odu.edu	+1 757 686 6203	+1 757 686 6214
Touze	Mr.	P.	NATO HQ	B-1110 Brussels BELGIUM	tsc&hq.nato.int	+32 2 707 4759	+32 2 707 4103
Turkes	Capt.	T.	TU Army	Kara Kuvvetteri Komutanligi Ankara TURKEY	tturkes@kkk.tsk.mil.tr	+90 312 411 2583	+90 312 411 6068
Tyte	Dr.	R.N.	DSTL	Farnboroguh Ively Road Hants GU14 0LX UK	rntyte@dstl.gov.uk	+44 1252 455659	+44 1252 455031

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Ucuncu	Col.	M.	TU General Staff	Genelkumay NMEBS Baskanligi Bakanliklar, Ankara TURKEY	murat.ucuncu@tr.net ucuncu@tsk.mil.tr	+90 312 402 2147	+90 312 425 0813
van der Kleij	Dr.	R.	TNO Human Factors	Kampweg 5 P.O. Box 23 3769 ZG Soesterberg THE NETHERLANDS	vanderkleij@tm.tno.nl	+31 346 356 266	+31 346 353 977
Von Baeyer	Dr.	A.	IABG	IK 31 Postfach 1212 D-85503 Ottobrunn GERMANY	baeyer@iabg.de	+49 89 6088 2127	+49 89 6088 2454
Wallshein	Ms.	C.	AFSAA/SAP	1570 Air Force Pentagon Washington DC 20330-1570 USA	corinne.wallshein@pentagon.af.mil	+1 703 588 6923	+1 703 588 8759
Wheatley	RAdm.	G.	Evidence Based Research Inc.	1595 Spring Hill Road Suite 250 Vienna, VA 22182-2216 USA	Wheatleyg@je.jfcom.mil	+1 757 836 8054	+1 757 836 8240
Wilder	Mr.	J.	TRAC-WSMR	Director USTRAC-WSMR ATRC-WBC White Sands Missile Range USA	wilderj@trac.wsmr.army.mil	+1 505 678 1024	+1 505 678 8074
Wilson	Ltc.	J.P.	UK MOD	DGD+D, SO1 COMD DEV (DES) Trenchard Lines, Upavon Pewsey SN9 6BE UK	sunaj95@aol.com	+44 207128 7607	+44 1980 615304

Surname	Title	Initials	Organization	Postal_Address	Email	Telephone	Fax
Witty	Ms.	S.J.	DSTL	DSTL Analysis Farnborough Hampshire GU14 0HF UK	Switty@dstl.gov.uk	+44 1 252 455146	+44 1 252 455062
Wright	Dr.	S.C.	DSTL	Building Q10 Fort Halstead Sevenoaks Kent TN14 7BP UK	scwright@dstl.gov.uk	+44 1959 892389	+44 1959 892504
Zanker	Dr.	P.M.	DSTL	A2/1016A DSTL Farnborough Hants GU14 0LX UK	pmzanker@dstl.gov.uk	+44 1252 455198	+44 1252 455 596

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Force structure planning		

14. Abstract

In 1998 The North Atlantic Treaty Organisation (NATO) published a Code of Best Practice for Assessing C2 (COBP), authored by SAS-002, which covered analysis of C2 at the ground forces tactical level in mid to high intensity conflicts. This 1998 COBP is being expanded by SAS-026 to address the broader spectrum of current C2 issues, including operations other than war, peacekeeping missions, cognitive factors, risk management, network centric concepts, and novel C2 arrangements. The documents contained in this publication discuss the extensions and revisions to the 1998 COBP, and provide best practices examples of current C2 analysis being conducted in member countries.

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Madrid 28033

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Hanover, MD 21076-1320

FRANCE
O.N.E.R.A. (ISP)
29, Avenue de la Division Leclerc
BP 72, 92322 Châtillon Cedex

GRECE (Correspondant)
Defence Industry & Research General Directorate, Research Directorate
Fakinos Base Camp, S.T.G. 1020
Holargos, Athens

HONGRIE
Department for Scientific Analysis
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Ministry of Defence
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