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Title: Results from C2 modelling and simulation for Edge Organisations		
Topic: C2 Concepts and Organisation		
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ABSTRACT

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The aim of the C2 modelling and simulation for Edge Organisations is to take a particular set of organisational characterisations, map this set onto a larger set of independent variables and then to use these to model different organisations interacting in an operational context with their differing degrees of freedom and feedback mechanisms in order to measure their operational effectiveness. The overall aim of the study is to establish a set of requirements for simulation models that will enable us to run experiments to explore organisational agility more fully.

The attributes used to characterise organisational form are derived from previous definitions of command functions, which have been extended to provide a specification that can be used to set (pragmatically at this initial stage) attribute parameters in a combat simulation. An example of an attribute parameter is the way (for the particular type of organisation) that internal conflicts are resolved between operating units when they are working with differing (and often conflicting) objectives and are carrying out sense-making with different information, beliefs and values.

It is assumed that Edge Organisations (EOs) have the ability to sense and assess external and internal structural pressures and re-shape themselves (and their environments) to adopt appropriate configurations whilst avoiding dislocation. Follow-on experiments will address re-configuration mechanisms for EOs, hence this paper covers the modelling requirements for such analyses.

The initial parameter set has been drawn from results of a war-gaming workshop that worked through a full space of potential independent variables to ensure that we had captured the defining parameters for the many different types of military organisation. The simulation runs, described in this paper, will help to establish range-scales for the independent variables and metrics required for the dependent variables in order to develop a comprehensive set of variables for an extended experimental campaign.

Essentially, the independent variables cover three sets of features:

- the characteristics of the organisational types and their C2 arrangements;
- the limitations and compositions of the organisational building blocks (MEANS constraints);
- the nature of the environment and particular assessment perspectives (restraints on WAYS).

The series of simulations also aims to highlight current capability gaps in simulation tools and analytical techniques to identify those that would be suitable for future experiments on organisational agility.

Introduction

This work forms part of a broader study of Edge Organisations by a team from QinetiQ in UK under the sponsorship of the CCRP[1] [1] [2]. The aim of the work is to explore and establish command arrangements for Edge Organizations, showing how these arrangements will work in many types of operational environment and how they perform against traditional, hierarchical organizations with more centralized command styles and against extremely decentralized organizations. Preliminary work concluded that an experimental campaign was required to test the thesis:

> *"…the organizational agility of Edge Organizations allows their operating units to exert more decisive influence over a wider range of adversarial organizations and within many types of operational contexts than those of less agile centralized or de-centralized organizations."*

The aim now is to explore the above thesis by simulating combat operations between organisations with different command arrangements (including extreme forms) to measure and assess the effects adopting different types of organisational form and function. Initially, war games with military experts were used to determine characteristics of command arrangements and to identify the parameters of the competing organisations that were then used as the inputs into a combat simulation. The simulations discussed in this paper are exploratory in nature and are meant to identify requirements for a more extensive experimental programme and to provide a set of recommendations for the development of models and metrics that would enable an experimental campaign to investigate organisational agility through command and control (C2) agility within a wide range of operational contexts.

A multi-phase approach has been adopted, as shown in Figure 1. The first phase characterised environmental aspects, adversarial force deployment, re-allocation of support units and general re-configuration in enough detail for initial combat modelling outline planning. The second phase characterized, more fully, the C2 arrangements for modelling purposes. Then, "proof-of-concept" modelling was carried out in a simulated combat environment between three different types of adversarial organisations as described in this paper. The results of these simulations were presented initially at CCRTS [2] and will be more fully discussed at 11 ICCRTS.

The third phase will include a more extensive experimental campaign in which a C2 arrangement for Edge Organizations will be refined within a full set of operational contexts and against a larger variety of adversaries. The recommendations for

[1] This work has been carried out under funding from **OASD-NII**

simulation specifications required for such an experimental campaign is a further topic for discussion in this paper. The future phases (3a and 3b) of the work are not reported here.

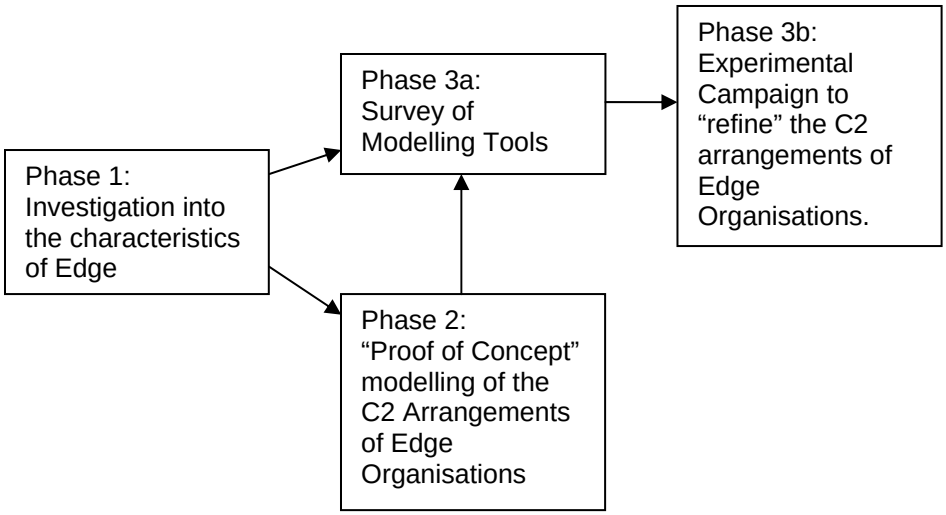

Figure 1: The approach to understanding the C2 Arrangements of Edge Organizations.

However, in order to capture the important aspects of future conflict operations, it is anticipated that future models must focus more on relationships, interactions and interdependencies rather than on physical combat activities and actions.

Investigation into the Characteristics of Edge Organizations.

In order to derive the modelling requirements, a set of attributes have been generated. The tables below show suggested lists of attributes that we believe can be used not only to characterize Edge Organizations but also to characterize a large range of organizational types ranging from those that have a command style that is top-down (with no initiative afforded to active operating units) to ones that are characterized as a 'cell-based' de-layered organization with a widely-dispersed and diffused sense of identity and purpose.

Organizational Attributes
Identity and sense of self
Generation, maintenance and dissemination of purpose
Groupings of operating units
Decision-making [Delegation of decision rights]
Sense making [Shared awareness of non-self]
Sense making [Perception of environment and changes]
Status monitoring and decision-making [Shared Awareness of self, including status and setting resource priorities]
Synergy [Shared awareness of self and own operation with respect to others]
Success measures

Table 1: Organizational Attributes

Organizational Building Blocks
Infrastructures and support (including logistics and interactions)
Personnel
Training
Doctrine (expression of)
Doctrine (use of)
Equipments

Table 2: Organisational Building Blocks

Environmental Context
Organization's own values and concerns about impact of its actions
Organization's perception of how others assess impact of its actions
Physical environment
Rates of Change
Target Specification
Terrain
Complexity of the Environment
Prior models of others' behavior modes, patterns
Boundaries (legal, tactical and operational)
Resources
Predictability

Table 3: Environmental Context

The attributes defined above, as developed through the characterisation phase, are consistent with those developed by the NATO SAS050 group [3] and also with those covered in Chapter 5 of "The Agile Organisation" [4] and hence they align well with the discussions in the recent CCRP book on understanding C2 [5].

Parameterisation of C2 arrangements and force structures

The attributes listed in Table 1 form the basis for the parameter set that defines the type of C2 arrangements and force structures represented in the combat simulations, which are as follows:

- Type 1: Strictly hierarchical force structure, top-down command (i.e. no delegation of decision rights to sub-ordinates) and fixed allocation of support units with no freedom to re-allocate.
- Type 2: More flexible force structure, mission-oriented command with associated decision rules for re-allocation of support units.
- Type 3: De-layered force structure, distributed command to lower-layer units and freedom to re-allocate support units across this lower-layer.

In addition to the C2 arrangements for force elements, there are C2 structures in place for logistics support units that can be parameterised so that the logistics organisation operates in a demand-led or pre-planned (supply-determined) manner. Parameters are also required to define the infrastructures for message passing (both to support Intelligence reports and own force situation reports) and the associated fusion processes are explicitly set.

So simulations to address questions of structural agility need not only to be able to parameterise all the many types of C2, force, HQ and information structures but also

to then be able to represent their coordination and synchronisation both at deployment and during run-time.

In our simulation experiments, the variables that represent the organisational building blocks (as in Table 2) for both the attacking force and defender similarly, are kept constant and reflect forces composed of regular current ORBATs (in order to keep the simulations unclassified and also uncomplicated by weapon effectiveness variability).

Characterisation of the operational environment

The CCRP C2 problem space [5] (as shown at Figure 2) outlines the following three dimensions:

- Rate of change
- Familiarity
- Strength of informational position

These dimensions capture the nature of the operational environment in terms of the operational tempo (rate of representative events), capability for understanding the adversary/environment (knowing what to look for and how to look for it) and ability to capture wanted information (being able to find it out and disseminate it appropriately).

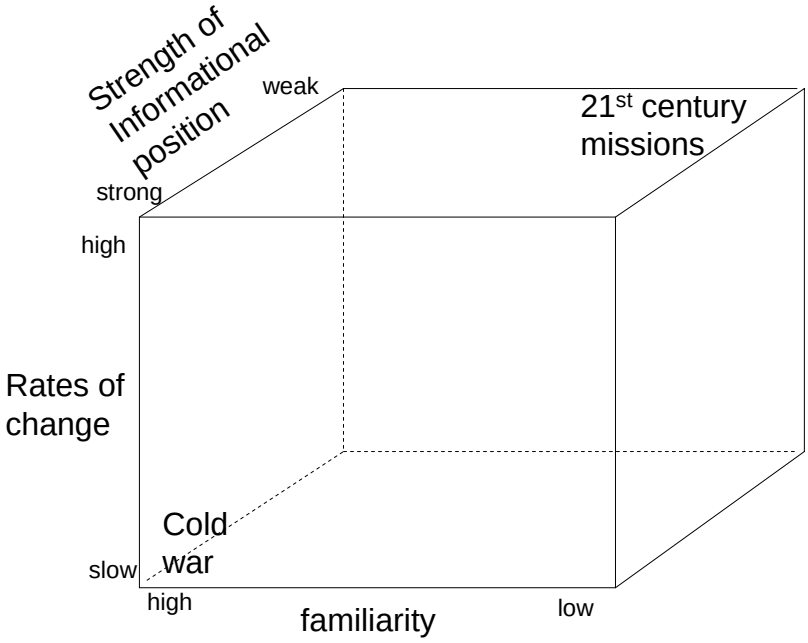

Figure 2: CCRP C2 Problem Space

One other important aspect of the C2 problem space is the degree of engagement (e.g. in terms of the significance that it affords in the socio-political sense); that is, how much are you committed and how critical are the operation outcomes.

The first phase of the work characterised the operational environment in these terms but to a finer degree (i.e. breaking out each of the three CCRP problem space dimensions) and are outlined in Table 3. For the purposes of this proof of concept study, the simulations take place in one broad region of this C2 problem space around a position of reasonably familiar forces and ORBATs (albeit structured very

differently) and terrain (relatively open desert with familiar types of infrastructure), relatively challenging rate of events for combat operations and representing current sensor technology and reporting structures (although the latter is variable concerning own force situation reports). This study does not address these problem-space dimensions as independent variables as the operational environment is not varied and remains within a fixed region of the problem space for all of the simulation runs.

Proof of concept modeling of C2 arrangements for Edge Organizations.

Phase 2 has involved using the output of the first phase and taking lessons drawn from the war-game sessions so that the organizational characterizations could be parameterized to enable us to run some “proof of concept” combat simulations.

The aim of the preliminary “proof of concept” simulations is to investigate operational effects and define appropriate operational and organizational metrics whilst varying the nature of the C2 arrangements of two adversarial forces in combat. This work used the ‘Alberts-grid’ as a reference framework [1] for defining the parameterization of information and intent sharing but it also required us to parameterize the force organisation and C2 structure in terms of the ways in which support units are deployed, employed and re-deployed across the force as the operation is on-going.

The key to parameterization of C2 arrangements is to capture both the constraints (in terms of the composition of a unit’s organic assets) and the restraints (in terms of the ways in which the units can be used and re-allocated across the force). The lines of authority and lines of responsibility must be made explicit in the force structures. The degree to which command intent must be adhered to by any unit is a key parameter.

The preliminary “proof of concept” simulations only address force-on-force combat, albeit between forces with different types of C2 arrangements (as Table 4 below).

		C2 arrangement of the DEFENDING force		
C2 arrangement of the ATTACKING Force		Type 1: Top-down	Type 2: Mission Command	Type 3: De-layered Unit-based
	Type 1: Top-down	Y	Y	Y
	Type 2: Mission Command	Y		Y
	Type 3: De-layered Unit-based	Y		

Table 4: Types of C2 arrangements modelled (i.e. denoted by “Y”) for each of the opposing forces in the proof of concept combat simulations

The simulation used within this proof of concept study is QinetiQ’s HiLOCA model [6]. HiLOCA is an object-oriented stochastic combat simulation capable of modelling aspects of C2 and information sharing with a degree of fidelity that is assessed as sufficient for a proof of concept study. Essentially the HiLOCA library of parameters falls into three “informational” areas relating to command, control and execution across four functional domains of organisational planning, J3 (fires, strike and movement), sustainment (logistics support), collection (sensor and J2 tasking).

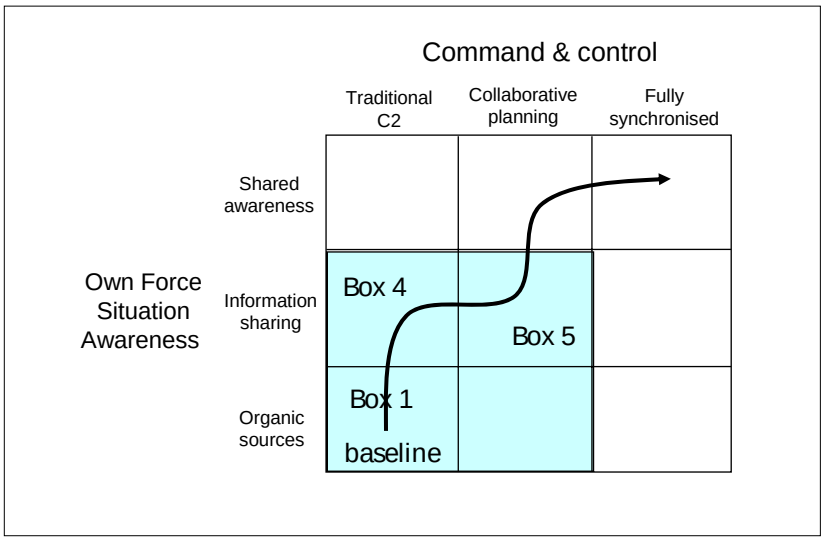

Figure 4: Alberts' grid (adapted from CCRP publication Power to the Edge)

In addition, HiLOCA is configured with two different libraries corresponding to the two combinations of parameters representing a combat force operating within Box 4 or Box 5 of the Alberts' grid (see Figure 4). Box 1 (not modelled) represents a baseline case for C2 and information sharing, Box 4 represents improvements through networking of own force information sharing and Box 5 represents improved (network-enabled) C2 processes. Box 4 and Box 5 parameters used in the model are similar to those derived for previous studies [7][8].

For each of the Box 4 or Box 5 combinations and for each of the combinations (i.e. those marked with a "Y" in Table 4) of C2 arrangements of the forces in combat we run several HiLOCA replications and three main categories of operational effectiveness measures are recorded: -

- Details on casualties and force strengths taken over time of both defender and attacking force.
- Measures of operational tempo (including rates of fire, movement and supply of ammunition, fuel, etc).
- Details on information sharing (including sensor reporting, picture compilation and sharing of command intent).

Results of this preliminary investigation (into the impact of differing C2 arrangements on operational effectiveness within the context of a desert-based vignette) will be presented showing, for example, changes in operational tempo due to varying C2 arrangements, C2 processes and Information sharing.

Challenges for modelling and simulation of agile organisations

The proof of concept simulations have exposed many problems and challenges; in particular maintaining synchronisation of the force elements as units are re-allocated and re-configured while the operation is on-going. It is clear that we need to extend

the notion of own force sense-making (i.e. what needs to be fed-back concerning the force distribution and its current effectiveness) to allow decisions to be made about when and how to re-configure the force such that some degree of sensible cohesion is achieved. The information that needs to be fed-back is more likely to be concerned with tightening or loosening the degrees of freedom afforded to the re-aligned operating units and their HQs.

The aspects of the on-going operation that need to be tracked and monitored (to achieve useful organisational agility) involve the connective interactions and interdependencies between the dimensions in the C2 problem space and the dimensions of the C2 arrangements. For example, if a force finds itself operating in unfamiliar territory against a strange adversary and it is proving difficult to collect information due to a high rates of change, then we need to be clear what needs to be adapted, what can be changed and controlled, who is/should be responsible for these changes and what the boundaries should be; in other words, how to re-establish the C2 arrangements to alleviate the "problems in the problem space". These issues are covered in more depth in associated ICCRTS papers [9], [10], [11] and [12].

Useful lessons can be drawn from running such proof of concept simulations which will benefit real operational commanders, as what proves difficult in a closed modelling environment (e.g. maintaining sensible force cohesion) will tend to be equally, if not more, difficult to achieve in actual future conflict operations involving agile organisations.

Combat simulations (in particular time-stepped or event-driven simulations) tend to be limited to modelling conventionally-organised units. Some, such as HiLOCA, are also able to model rebel forces with randomly-selected ORBATS carrying out bouts of reactive fighting while defending captured infrastructure. However, this is not going far enough and cannot help us to understand and model eventualities such as those on London Underground on 7th July 2005.

The major challenge for combat modelling occurs when there is no clear distinction between own and enemy (i.e. "Red and Blue"); indeed, in reality, operating units often closely share their environment, resources, infrastructures, etc and have multi-faceted roles, relationships and interdependencies. So instead of employing just sensors to look outside "the organisation" we should also be taking a look at regulatory mechanisms and value systems that give form to the shared space. Measures of effectiveness will need to be re-thought so that they are not tied to results of kinetic actions (combat strengths, tempo, etc) but reflect the nature of the shared operating space as a whole.

Therefore, we need to develop constructs, methods and models that can identify and respond to drivers derived from the linkages and connections between units who share an operational space and these will be driven by individual requirements for power and comfort (based on subjective values). These are usually taken as givens because they are the assumed values that create the need for combat operations between adversarial forces. Now these values (that form constraints, restraints and desires) must be fully-exposed and made explicit as independent variables in future modelling to support our understanding of agile organisations.

In order to capture the important aspects of future conflict operations, (hence cover the entire space of characterisation of C2 arrangements, organisational building blocks and environment) our models must focus more on relationships, interactions and interdependencies rather than on physical combat activities and actions.

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