11TH ICCRTS COALITION COMMAND AND CONTROL IN THE NETWORKED ERA

Title of Paper: **Developing A Requisite Analytic Trade-Space For Assessing Agile Mission Grouping - Problem Definition For The Development Of The DARNSTORMS Model**

Topics: **Cognitive Domain Issues, Social Domain Issues, C2 Modelling and Simulation**

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Developing A Requisite Analytic Trade-Space For Assessing Agile Mission Grouping - Problem Definition For The Development Of The DARNSTORMS Model

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Abstract: There is an increasing demand on our ability to understand how international military forces may improve their effectiveness in coalition operations, while simultaneously national defences forces have to make investment trade-offs in order to achieve highly networked capabilities both across their own forces and in coalition with allied forces. This reality places new demands on defence analysts to make rational judgments and decisions on investment trade-offs across a much wider scope than has been traditional in defence operational research. For example, the process of dynamic formation of mission groups involves much more than just physical capabilities and bandwidths. Rather, it is intricately and inseparably linked to the cognitive, organisational and socio-cultural aspects of human interaction. Though much is already known about these problems, both from research and operational experience, virtually none of this knowledge can be brought to bear through existing analytic tools.

In this paper we will describe the trade-space problems facing defence analysts in both UK and Australia, and how they may be addressed through the joint development of the DARNSTORMS model, integrating the Australian DARNOS model and the UK STORM algorithm. This paper is the first of three being offered to the Symposium; the other two will focus on theoretical synthesis and implementation issues.

1. INTRODUCTION

At the operational level, the success of Network Centric (Enabled) Warfare depends fundamentally on the ability to achieve effective collaboration between distributed team members (operators and warfighting capabilities) by taking advantage of superior information networks. This demands not just the ability to communicate and share information freely and effectively, but also the ability to successfully share an understanding of other teams members capabilities and world views, of the task and its dependencies, and of the situation (the common operational picture). As well as a mature mutual understanding, a common trust amongst the operators is critical to enable commitment to cooperative action. [1]

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A number of key elements have to be in place for a force to be capable of agile mission grouping (AMG). For example, it needs to be supported by the right technologies, such as the right communication network and bandwidth; the right command and control (C2) structure and the right information network architecture; the right doctrine and culture; and the right people. A moment's reflection soon reveals that supporting decision-making across such a broad combination of issues present a huge challenge to the analysts. The problem becomes even more formidable in coalition operations, in which prior operational

knowledge of one another, as well as joint training and exercise may not have been possible.

As the UK Vice Chief of the Defence Staff said in 2003, "NEC will have profound implications for our future command and fighting capability... there will need to be significant activity across all Lines of Development if we are to ensure the successful implementation of NEC. There will also be a need to address multinational interoperability in parallel with the Joint dimension of NEC."

Facing the highly complex interplay between these elements and the competing demands on resources in a modern networked force, it becomes apparent that most national defence forces have to make investment trade-offs in order to achieve highly effective networked capabilities both across their own forces and in coalition with allied forces. The need to determine, with a reasonable degree of rationality and accuracy, the right trading-space for a particular defence force will be a particularly serious challenge for senior decision-makers in most defence forces.

Some of these analytical challenges may be alleviated to an extent with the help of modelling and simulation. A carefully designed modelling and simulation tool can give analysts the freedom to explore a range of issues over a wide parameter space, finding possibly the local maxima (minima) here and there, in order to provide the senior decision-makers a number of possible options for manoeuvring in a quite often narrow trading-space.

This paper will first discuss in more detail significant challenges related to the existence of dynamic team forming in a context where teams may have difficulty achieving full maturity, linking these both to effectiveness consequences and to factors in the team composition, context and task that shape the phenomena. We will then describe some recent developments in models in both DSTO and Dstl for addressing some these issues.

2. SIGNIFICANT CHALLENGES

UK Defence Policy is now focused on “delivering flexible forces able to configure to generate the right capability in a less predictable and more complex operational environment. This will require us to move away from simplistic platform-centric planning, to a fully “networked enabled capability” able to exploit effects-based planning and operations, using forces which are truly adaptable, capable of even greater levels of precision and rapidly deployable” [2]

The Australian Defence Force (ADF) similarly seeks a network centric, agile capability. In addition to recognising the key role played by information and communication technologies, the ADF places great emphasis on the role of the human operators [1]. As the Australian Chief of Defence Force, Air Marshall Angus Huston, stated in 2005,”There are the strict systemic protocols between sensor, shooter, the command and control system, and the people that utilise them. But the key to NCW is the relationships engendered by people through the net.”

Agile Mission Grouping (AMG) is a solution strategy to cope with: a) an increased dynamism in the operations space, making it less practical to pre-ordain mission group composition and way of working; and b) a desire to make best use of fleeting opportunities to achieve useful effect that arise without warning. The concept of AMG has been enabled by advances in information networking, but the act of implementing AMG in practice will severely challenge Command and Control capability well beyond the Information Domain, particularly in a coalition context,

In typical defence analysis, military forces are treated as formal organisations characterised by a purposive and task orientation, coherent goals, established structures, determined roles and rules, shared culture, coherent commitment to act, and stability over time. To effectively understand and assess AMG requires the analyst to re-consider this formal view. By analogy to the shift in decision making analysis from rational choice towards naturalistic decision making [ref Decision making in Action book], the conception of organisations needs to pay more attention to informal characteristics such as social network orientation, multiplicity of unshared goals, ad hoc structures, emergent roles and rules, multiple cultures, varied levels of commitment, and adaptability over time.

At the core of even the most professional military team is a human collective whose behaviours are founded in a rich mixture of social and cultural influences. Formal doctrines and ways of working, acquired through membership of organisations and institutions, are laid on top of informal, acquired practices that derive from a lifetime of experiences. Such experiences arise from family life and from membership of a variety of social groups.

Acquiring new collective behaviours takes time. Teams need to interact in order to mature their knowledge of how to work together to formulate and achieve shared goals. Teamwork and task work skills are developed through practise and repetition, as is the trust necessary to allow committed participation, particularly in risky contexts.

The research of Tuckman and Jensen [3] identifies stages of team formation and maturing, each associated with significant challenges as team members seek to develop key shared understandings. The stages in the Tuckman/Jensen team maturity model are Forming, Storming, Norming and Performing. Later versions add an Adjourning stage, recognising the temporary nature of many teams. In a further extension to the construct, Mathieson *et. al.* [4] has added Transforming in

recognition of the fact that AMG will involve teams which adapt and change in composition, context and/or task assignment.

In the Forming stage when the group is established, it is important that teams agree on collective goals, ground rules, roles, and responsibilities. This communication ensures that each team member understands why they are there, what is expected of them. AMG in a coalition context, especially where team members come with different default command styles, can prolong the formation of collective goals and acceptance of team membership. In looser coalitions, where even strategic goals may not be fully shared and multiple goals are normal, ambiguities continue into the Storming stage.

Storming is a conflict stage in the team's life and can be a very uncomfortable period. Members bargain with each other as they try to sort out what each of them individually, and as a group, want out of the group. Individuals reveal their personal goals and frustration and disagreement arise on issues of leadership, power, control, and influence. If the team members do not share clear understandings of their respective roles then these need to be clarified through time-consuming interaction. During this time the team learns how to work together, drawing on their teamworking skills and any commonality in their cultural background.

Once the group dynamics are fairly established, the Norming stage focuses on the goals set during team formation and how they will accomplish those goals. Members must communicate to determine priorities and assess how well they are operating as a group. The members of the team develop ways of working, closer relationships and camaraderie. The questions of who will do what and how it will be done are addressed. A shared understanding of the task at hand, its dependencies and requirements, and of the resources available to the team, is critical at this stage. Working rules are established in terms of norms of behaviours and role allocation. Where team members do not already share well rehearsed norms, perhaps coming from quite different parent organisations, explicit communication and strong leadership will needed to develop effective working practices that achieve good task performance.

In the final Performing stage the team begins to see the success of working together as a group. Productivity increases as workers are empowered, fewer conflicts arise, and more time is focused on achieving objectives. Belief in the team concept is strengthened, greater trust is given and received, and coordination can include more implicit and anticipatory elements. Mature teams are able to be more creative in adapting to changing circumstances without the need for as much explicit interaction and re-planning.

In an AMG context it may be assumed that many teams will never reach full maturity and those that do may need to undergo changes such as adding or losing members or key resources, taking on a new mission, or break up entirely. Change will usually result in the team regressing to an earlier stage of maturity, requiring them to recognise the changes and revisit challenges more than once.

The causes of variable team maturity are various, as are their consequences. Less mature teams will necessarily expend more of their time and energy on teamworking activities and less on the task in hand. This will impact on the efficiency with which task work can be done, an effect compounded by lower collective skill in task execution.

Alongside the task performance effects of maturity, one should expect to see teams adapting their behaviours to their capabilities. Recognising their limitations, immature teams who have the choice may seek easier tasks, or choose to perform them in ways that require simpler coordination processes. Similarly, team organisation may adapt to reduce the effective difficulty and richness of the task. This is essentially the same effect recognised by Mintzberg [5] in his discussion of organisational form arising in response to task and environment complexity and organisation composition.

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However, while Mintzberg's forms provide a powerful generalisation of adaptation in organisational form, the theory based is not strong enough to provide a reliable algorithmic prediction of a team's task behaviour in the context of mal-adapted organisations or ones still in the process of adapting. Without such an algorithm, the appropriate analytic approach is to treat team adaptation as a control variable and to systematically assess its team performance impacts. Factors in team composition, context and in the team's task that may arise from adaptation will be considered as scenario variables,

Team composition factors represent the cultural composition of the team, particularly the coherence of social and organisational cultures and the extent of personal socialisation between team members. Task skills (the 'know-how' of task performance), teamwork skills, leadership style and organisational coordination style are also key factors associated with the team itself. Task factors include task difficulty, richness and novelty. Context factors include the quality of the team's goal and situation briefs, team co-location, and the adversary environment in which the team must operate.

These factors and their predicted impact on team performance are discussed in more detail in Tidhar *et al.* [6]. In order to assess the implications of team adaptation, these factors will need to be subject to a systematic sensitivity analysis. A proposed method for sensitivity analysis is described in ShibiMarr *et. al.* [7].

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Since many of the factors to be studied have impacts which will be dependent on the specifics of context, it is necessary to define a scenario within which to conduct

analysis. The next section outlines a suitable coalition scenario, with the scope to allow a suitably broad factor assessment.

3. A Coalition Operation Scenario

To put the above discussion into context, we describe a variation of a scenario developed by UK analysts for a NATO research group (SAS-050 [8]), which is then combined with an Australian scenario. The scenario comprises a humanitarian operation, involving the UK and Australia as coalition partners to provide support to aid agencies in a third world country. The familiar setting of UK and Australia working together has the advantage of being a relatively simple place to begin our discussion, which can then evolve into a more complicated situation with the participation of a third-world country.

The scenario begins with a powerful and aggressive country, Tetlovia, invaded its neighbour, Keswonia, with the aim of capturing Keswonia's deep-water port, Port Kesw, and the largest city of Keswonia, as well as taking control of the entire Keswonian East Coast with the Indian Ocean. This could have serious impacts on both regional and international trade routes.

The Keswonian army is putting up strong resistance but they are not expected to be a match for the much bigger Tetlovian army in the long term. Meanwhile, a huge humanitarian crisis begins to emerge as Keswonian refugees escape the advancing Tetlovian army and move towards Port Kesw. The Keswonian government seeks urgent intervention and humanitarian assistance from the United Nations (UN).

The UN passes the appropriate resolutions and the UK with Australia offer to form a task force, based on forces currently taking part in combined exercises in a nearby region, to provide military protection to the refugee camps and UN aid supply and workers.

The government of San Serriffe, an island state located not far off the coast of Keswonia, offered to be used as a base for Australia and UK operations in support of UN resolution.

As the UK and Australian forces moved from the state of combined exercise to the formation of a humanitarian intervention coalition task force, a joint HQ is set up in San Serriffe to coordinate both logistic support to the UN aid supply, such as providing land transport to the refugee camps, and the military protection of the refugee camps, UN aid workers and the UN supply line by sea, as well as Port Kesw. The military protection becomes essential as Tetlovian air force tries to intimidate the UN by launching air raids against refugee camps and UN supply ships.

During the initial stage of the operation, the main participants are the Australian and UK forces who focus on stabilising the humanitarian situation and providing logistic support. Later on, as the operation becomes more intensive, and with more CTF troops on the ground of Keswonia, Keswonia officers joined the CTF HQ to provide the operational knowledge of the local force as well as local information and custom. The introduction of the Keswonian officers represents the transforming phase of the team.

4. Modelling response

The following sections discuss our attempt at combining the DSTO DARNOS model and the Dstl STORM algorithm into a single simulation package known as DARNSTORMS that will support analysis across a significantly wider scope of the capability trade-space than hitherto available. We will use our coalition scenario to illustrate the underlying concept of applying DARNSTORMS.

4.1 DARNOS

One attempt at redressing the analytical problems has been the development of the *Dynamic Agents Representation of Networks of Systems* (DARNOS) modelling and simulation tool, which was originated by the Defence Science and Technology Organisation (DSTO) and jointly developed with KESEM International. DARNOS [9, 10, 11] is a modelling and simulation system that has been designed, in the first instance, to allow the Australian Defence analysts to carry out comparative analyses of operations in the NCW context with a special emphasis on the dynamic management of the information environment and C2. DARNOS achieves this by taking an organisation-oriented approach to modelling the dynamic interactions between players in a networked organisation, where the impact of different C2 and information network structures on the operation of the organisation (e.g. a team or an AMG) can be most significant.

Therefore, DARNOS is well suited for studying trade-off problems such as whether the Australian Defence Force (ADF) should invest more in network technology versus weapons with greater fire power; or to invest more in niche capability with the aim of working more effectively with coalition partners.

4.2 STORM

STORM is an algorithm developed by Mathieson *et. al.* [4] that combines the Tuckman's team maturity process [3] with Noble's theory of knowledge enablers [12] to create a bridge between the social and cultural characteristics of the team, from which variations of knowledge are derived, and team performance, based on maturity relative to the task.

The work of Noble is founded in transactional memory theory, which emphasises the role of team members as knowledge resources, effectively external memory for their colleagues. Tuckman's team maturity model can be interpreted as a process of acquiring knowledge in various categories to enable the team to perform better, STORM integrates Noble with

Tuckman to model the dynamic development of a team from first formation to full maturity, and the impact on this progress of changes to team composition, context and tasking.

Thus, STORM can be added to an extant model of team activity and extend its capability to include key social and cultural dimensions relevant to agile coalition operations.

4.3 DARNSTORMS

DARNSTORMS is a collaborative project that aims to combine the organisation/team formation modelling capability of DARNOS with STORM's ability to model team maturity and performance as a function of different degree of knowledge each team member brings to the team, and the effect of prior knowledge that team members have of each other.

The key to the integration design of DARNOS and STORM is a set of variables, known as settables, which form in effect the interface between DARNOS and STORM. In a simulation, these settables will be used to exchange information between DARNOS and STORM about the team composition (who the members are; how good they know each other and their experience and expertise etc.), the nature of the task relative to the team experience, team maturity during the simulation (the unfolding of the scenario) and so on.

In the following sections we will use our coalition operation scenario to illustrate how STORM and a host model like DARNOS may be used together to explore the impact of team member knowledge and their (prior) knowledge of each other may contribute to improving the team performance in a coalition environment.

4.4 Modelling of Real-Life HQ

In view of the discussions in Sections 2 and 3 above, we can now explore several possible variations of team maturing process in the CTF HQ: *a*) many of the officers from both countries have worked together before in action, such as in the Gulf Wars; *b*) at least some of the officers from the UK and Australia forces have worked together in joint exercises and have a good understanding of each other's methodologies and culture; *c*) none of the officers have worked together before; *d*) any of the above with and without socialisation outside of work shifts (off-task socialisation); and *e*) the introduction of the Keswonian officers into the CTF HQ.

It is clear that the first case has the best chance of producing a team that can work together effectively in a short space of time. If additional opportunity of off-task socialisation is included, one would expect the team to mature in the shortest time possible. Whereas, on the other hand, if none of the officers have met each other before and originate from different command cultures, the Storming process is likely to be longer and more difficult, with many differences and conflicts to resolve. Furthermore, if the officers have little or no opportunity to socialise out of work shifts, the Norming process will also take longer. The overall consequence is that the team, left to its own devices, may take much longer to mature and perform effectively. (Of course, a number of possible interventions, both technical and organisational, could be deployed to ease team maturation and the DARNSTORMS development is aimed precisely at allowing assessment of such interventions.)

Finally, the appearance of Keswonian officers will initiate an entirely new process of transforming, storming and norming. Both this new process and the workings of a tri-nation HQ will probably represent a more realistic situation in today's world.

4.5 Scenario Evolution in DARNSTORMS

Having established the context of the scenario and the possible team combinations in the CTF HQ, we turn our attention to how DARNOS and STORM may be used together to examine different ways this UK and Australia coalition partnership may unfold based on different HQ arrangements, different prior experience in joint exercise and posting, and different scenario assumptions.

In a DARNSTORMS simulation, DARNOS will begin by forming the entire Coalition Task Force (CTF), and in particular the members in the CTF HQ who will work together to direct the operations. Within the HQ, based on each member's experience, knowledge, skill and prior knowledge of one and other, DARNOS will provide parameters on team composition and task that are combined with context parameters to set the initial values of the settables, which are used in STORM to calculate the team maturity and performance parameters over a period of operational time (e.g. days or weeks). Upon completion of the STORM calculation, STORM feeds the maturity level to DARNOS in order to determine the level of skills (via the proprietary Expertise Blocks) with which the team members in the HQ perform their tasks. DARNOS will then carry out the calculation of the next task based on the (improved) knowledge and skills.

4.6 The Social and Cultural Consequences

Let us now examine in greater detail how the social and cultural aspects of team dynamics, and their impact on team performance, are modelled in DARNSTORMS via the settables.

In the scenario described in this work, the majority of team forming and storming activities is expected to have occurred in the HQ in directing the logistics operations in the early stage of the operation, during which there is relative peace and the officers will have the opportunity to get to both work and socialise together, learn each other's culture, skills and knowledge. Based on the initial values of the settables, STORM calculates the level of team maturity based on

the task difficulty and skill at the end of this period (e.g. a number of weeks).

At this point, the settables are updated to indicate the new level of team maturity, and the information is passed on to DARNOS for evaluating the performance of the team in the next phase of the operation. For example, now the Tetlovian air force may have increased its activities, posing an increasing threat against the refugee camps, the UN air supply line and their workers. In response, the UK and Australian maritime and air forces work on building up their air defence capability, increasing air patrol and interception.

The real test of the team maturity will come at the critical moment when Tetlovian Air Force launches stealth raids against Port Kesw and UN aid ships using terrain masking. The level of team maturity achieved within the CTF HQ will determine the team performance in directing the air defence operation.

In summary, the team forming and storming phases in this scenario happen during the relatively low tempo, build-up phase of the operation. STORM calculates the new values of the settables at the end of this and informs DARNOS of the team's new skill and knowledge set, with which DARNOS will now evaluate the operational performance of the CTF in the high tempo phase of air defence against the Tetlovian air raids.

5. SUMMARY

In this work we have described some of the important challenges facing both the UK and Australia in our respective implementation of the concept of Network Enabled (Centric) Warfare. In particular, we have discussed the need to find an optimal solution in the investment trade-space. The UK adoption of the concept of agile mission grouping, and similar approach taken by Australia, have a common emphasis on understanding the role of human operators in a networked force, and their interactions, both in a co-located environment and via the information network. The DARNSTORMS project being jointly developed by DSTL and DSTO is an attempt to use modelling and simulation to examine some of the human issues that may emerge in the implementation of the concept of agile mission grouping.

6. ACKNOWLEDGMENT

This work is in part funded by the Long Range Research Task (LRR05/292) of Defence Systems Analysis Division, DSTO. This work is also funded in part by the OA Domain of Output 4 of the UK Ministry of Defence Research Programme (OAD 05 02 001).

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