11th ICCRTS
COALITION COMMAND AND CONTROL IN THE NETWORKED ERA

Designing and Assessing a Future C2 Model

Topic(s): C2 Concepts and Organizations (or C2 Analysis)

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ABSTRACT

As part of its process of transformation, the UK Ministry of Defence is considering whether it is possible to enhance Command and Control (C2) in the networked era. This paper describes the structured method that is being used to assist senior commanders in establishing their preferred model for UK operational and tactical C2 out to 2020. The method has three stages: Define, Test, and Decide. The Define stage involves the conduct of a structured workshop, involving senior commanders, to generate a set of assumptions that define their preferred C2 model. The Test stage employs a coherent programme of research, analysis and experimentation to check that the proposed model is truly 'better' than maintaining the current C2 model into the future. This addresses questions such as 'Is it better in realising military effect?', 'What is the impact on HQ manpower and training needs? and 'What is the likely impact on force structure?'. The Decide stage involves exploitation of the scientific testing to inform decisions on future C2 and the impact on issues such as future equipment needs and future force structure. The paper describes the Define workshop approach, the Test framework that has been established, and notes the Decide process that brings it all together.

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INTRODUCTION

United Kingdom (UK) Forces are in the early stages of a transformation that is based around an investment in Network Enabled Capability (NEC). It is expected that this investment will provide "decisive advantage through the timely provision and exploitation of information and intelligence to enable effective decision-making and agile actions" [1]. NEC is to be implemented through the "coherent and progressive development of Defence equipment, software, processes, structures, and individual and collective training, underpinned by the development of a secure, robust and extensive network of networks" [1].

Evidence from a broad range of studies, experiments and operational lessons indicates that the UK can expect significant benefits from its investment in NEC. A number of these benefits were described in a paper to ICCRTS10 [2]. In summary, the evidence suggests that NEC will allow UK forces to operate quicker and better, and with reduced risk of fratricide. It also highlights that enabling dynamic collaborative working can improve operational capability, particularly when agility of command and control (C2) is combined with improvements in the quality of information available. For example, in an experiment, a UK digitised force with agile C2 found that the time taken for an attack was only a third of the mean of all other digitised attacks (where current doctrine was used), and half the time of the fastest non-digitised attack.

Growing awareness of the potential benefits of NEC has led the UK Ministry of Defence[1] (MOD) to now develop its concept for C2 in the networked era. This paper describes a specific activity[2] to explore whether it is possible to enhance the Command[3] and Control[4] of expeditionary operations at the operational and tactical levels. This includes situations in which the UK is part of a coalition force. Interest is focussed on three key issues:

- Is there still a need to maintain environmental componency[5] in operations, or is there a better way of organising C2?
- Is it still necessary to think in terms of strategic, operational and tactical levels of command, or can these now be compressed?
- To what extent can command and control be geographically separated in the networked era?

These are complex issues. To tackle them, UK MOD has embarked on an ambitious, co-ordinated programme that combines military judgement and scientific testing, to inform decision-making. This paper describes the structured approach that is being

[1] The development of the UK concept for networked C2 is led through the MODs' Development, Doctrine and Concept Centre (DCDC).
[2] Under the leadership of the Vice Chief of the Defence Staff.
[3] "The authority vested in an individual of the armed forces for the direction, coordination, and control of military forces". [3]
[4] "That authority exercised by a commander over part of the activities of subordinate organisations, or other organisations not normally under his command, which encompasses the responsibility for implementing orders or directives. All or part of this authority may be transferred or delegated". [3]
[5] Current NATO and coalition doctrine envisages a functional component command or Service component command responsible for the planning and conduct of a maritime, land, air, special or other operation as part of a joint force.

used to assist senior commanders in establishing the way forward for UK operational and tactical Command and Control in the networked era.

DEALING WITH THE PROBLEM

The approach taken to dealing with this problem is consistent with the guidance provided in the NATO Code of Best Practice (COBP) for C2 Assessment [4]. Considerable attention was given to clarifying what was to be addressed and why (defined as problem formulation in the COBP) and how it could be accomplished (solution strategies in the COBP). This was aided by the key decision-maker being engaged fully in the process.

PROBLEM FORMULATION

It was clarified that the aim of the effort is to inform the development of UK operational and tactical C2 capabilities for expeditionary operations out to 2020. The focus is the deployed UK Joint Commander, covering the activity currently enacted by Permanent Joint Headquarters (PJHQ) and the Component Commanders.

The primary measure of success of the approach is the extent to which the outputs of the programme are exploited and used to inform key decisions by MOD stakeholders. A key requirement was the inclusion of a one day workshop involving senior commanders and key stakeholders. These two criteria drove the solution strategy.

SOLUTION STRATEGY

Given the need to ensure that the outputs would be used in support of decision-making, a process of reverse-engineering was used to plan the approach (Figure 1). This began by considering the end-point and identified the decisions that MOD would need to make before implementing a change in C2 model. These decisions would need to be underpinned by evidence that the proposed changes would be of benefit to UK defence.

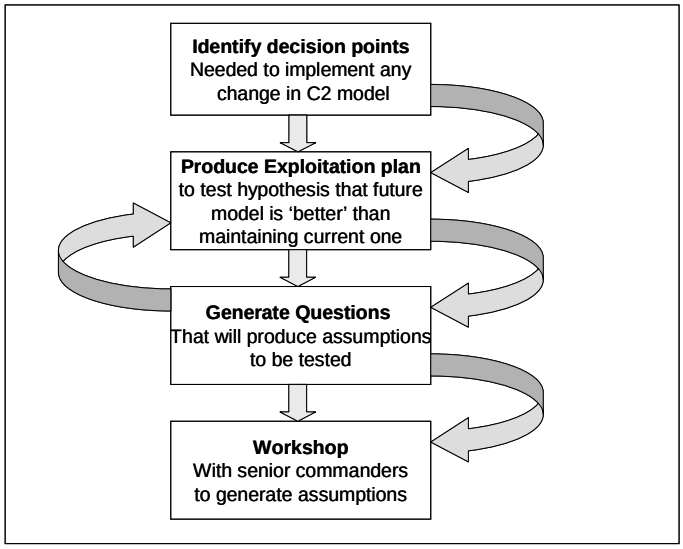

Figure 1: Reverse-engineering process to plan method

The complexity of the potential C2 changes meant that no single method or study would be able to consider their full impact. Thus, a coherent programme of research, analysis and experimentation was needed to test the hypothesis that the proposed future C2 Model was better than maintaining the current one. Testing the hypothesis required that a starting set of assumptions be created to describe the proposed networked-era C2 model. These starting assumptions would be generated through the conduct of a workshop with senior commanders. In other words, working backwards through the output-input path established the overall structured method and the required flow of information through the whole process, starting with a workshop to define the proposed networked-era C2 model.

THE STRUCTURED METHOD

A three stage approach, as shown in Figure 2, was agreed as the basis for proceeding. The first stage, **Define**, generates a set of assumptions that define the proposed Future C2 model. This stage involves all key stakeholders, including senior commanders and those involved in future decision-making on issues such as force structure and future equipment programmes. The second stage, **Test**, through a programme of science, tests the hypothesis that *"Adopting the proposed Future C2 model is better than maintaining the current one"*. The third stage, **Decide**, brings key stakeholders together to decide on the way ahead, informed by the test findings. Early findings from the testing may lead to the need to challenge and revisit some of the assumptions generated in the initial Define stage, leading to some iteration. The first two stages are described below in more detail. There is no further discussion of the Decide stage. The Define stage has just completed at the time of writing this paper. By the time of ICCRTS11, the method will have progressed to the Test stage.

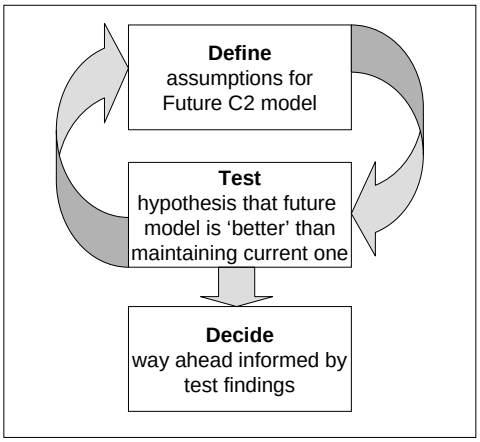

Figure 2: Three-stage structured approach

DEFINE STAGE

The focus of the Define stage was the conduct of a one-day workshop involving senior commanders, of between 1* and 4* level, to inform the creation of a set of assumptions on their preferred model of Future C2. A set of essays was provided to attendees, ahead of the workshop, to help them achieve a common understanding of

the issues of interest and to provoke thought. These were produced by relevant experts on:

- The essence of command and what this tells us about the nature and functions of HQ staff and the ability to separate command from control
- Shifts in the strategic context by 2020
- Improvements to C2 capability that will result from funded UK technology investments in the 2015-2020 timeframe
- How relevant human issues, including cognitive constraints and trust issues, will affect commanders and their staff in a Network Enabled C2 environment.

The workshop was split into three working groups, each of which explored the strengths and weaknesses of different C2 models in a selection of scenarios. Discussions in these groups prepared participants for a final plenary session in which electronic voting was used try and reach consensus on the characteristics of the proposed Future C2 model. These activities are described below in more detail

Working Group Activity

Each working group considered three different scenarios; three was considered sufficient to test the agility and robustness of any proposed changes to C2. The scenarios were agreed with the relevant UK authority, to ensure that they were policy compliant (and hence that outputs based on them could be used in decision-making). Each differed in terms of operational lead, scale of effort and operation type. Working groups explored:

- What are the most stressing aspects of each scenario, in terms of C2?
- Which factors influence this (e.g. is it scale of effort, nature of coalition, etc)?
- What are the key functions of Command and Control?

The five C2 models described in Table 1 were considered in each scenario. It must be noted that, with the exception of the baseline, the working groups were not provided with pre-worked examples of what the models would look like: they were asked to derive their own vision of the possible alternative models.

Model type	**Description**
Baseline	This describes the current approach to C2, which includes environmental component commanders, the deployment of operational and tactical HQs, and the geographical co-location of a commander and his full staff. This is the baseline against which the other models are to be compared.
Removing/reducing environmental componency	To explore whether there are any possible alternatives to having Land, Air, and Maritime Component Commanders.
Compression of Command	To explore whether there are any possible alternatives to having three discrete and distinct tiers of strategic, operational and tactical command.
Geographical separation of Command and Control	To explore whether there are any possible alternatives to having all staff geographically co-located with the commander.
Combination	Mixes of the three alternative models above.

Table 1: C2 model options for consideration

Working groups explored the strengths and weaknesses of the different C2 models, and considered whether any of the alternative models are "better" than the baseline model. To assist this comparison, the set of metrics shown at Table 2 was used. The first five are taken from the measures of agility[6] in the UK Joint High Level Operating Concept [6]. The next two are derived from assessment of the risks of Network Enabled Capability, and are intended to ensure that the cognitive aspects of Command are given adequate attention in the assessments. They, in essence, address aspects of sense-making as given in the NATO SAS-50 C2 Conceptual Model [7]. The final two metrics measure the strengths and weaknesses against two of the UK's key drivers on future capability.

Flexibility	Not being dependent upon a single course of action or only one way of operating.
Responsiveness	The speed with which we react to a change in the environment relative to potential or actual adversaries.
Adaptability	An aptitude to learn rapidly about new environments, especially when faced with the unexpected – and act accordingly.
Resilience	The endurance to continue to provide C2 over the duration of the operation.
Robustness	Both physical resilience and the versatility of our forces to perform across the full spectrum of operations
Shared Understanding of Command Intent	The ability to communicate intent to subordinates and trust that it has been understood.
Enabling Leadership	The ability to inspire subordinates to undertake hazardous or undesirable tasks and enable mission command.
Interoperability	The ability to achieve the necessary coalition, joint, cross-government and inter-agency liaison and interaction at the operational level.
Resources needed	In terms of footprint in theatre and cost of operation.

Table 2: Metrics for working-group comparison of C2 models

Electronic Voting

The final stage of the workshop was a plenary session using an electronic voting technique to structure decision-making. This method was chosen for two main reasons:

- To ensure that a set of clear conclusions were drawn on which characteristics of a Future C2 model were preferred and why, and
- To minimise any potential problems in military rank overtly influencing individual views or "talking time". Electronic voting means that opinions are initially expressed anonymously, giving everyone the opportunity to offer their unbiased view.

[6] These are similar to the measures of agility proposed by Alberts and Hayes, Power to the Edge [5].

Electronic voting works by giving each workshop participant an infra-red keypad with numbered buttons. Workshop participants were presented with a series of questions and the voting opinions available to them on each question. Each voting opinion was associated with a number. For each question, they registered their opinion by pressing the appropriately numbered button. All votes were collected electronically and displayed graphically[7]. The workshop chairman then led a discussion using the voting results to structure the debate. Generally, a second vote was taken following the discussion, to see if opinions had changed following the exchanges that had taken place. It is important to note that it was the discussions and the balance of voting that generated the main insights of the workshop. Outcomes such as 'the average voted opinion was 3.5' are totally meaningless and are not a valid outcome of the process.

The questions were in two blocks, as shown at Tables 3-1 and 3-2. The Block 1 questions were designed to seek agreement on the preferred characteristics of a future C2 model, and to understand the reasons in terms of their impact on the C2 assessment criteria. The Block 2 questions explored specific manpower issues**.** It must be emphasised that the set of assumptions on future C2 will evolve from the discussions that these questions generated – and not by a simple counting of votes. The technique used these questions to conduct a structured discussion of the strengths and weaknesses of different options, from which the chairman drew the conclusions to be taken into the next stage of Testing.

Block 1 Questions	**Voting options**
Q1-1. What do you believe would be the impact of removing or reducing environmental componency, compared to the effectiveness of the baseline model?	1. Degradation in both Command and Control 2. Degradation in Command but not Control 3. Degradation in Control but not Command 4. No impact on either Command or Control 5. Improvement in Command but not Control 6. Improvement in Control but not Command 7. Improvement in both Command and Control
Q1-2. What do you believe would be the impact of compressing command, compared to the effectiveness of the baseline model?	
Q1-3. What do you believe would be the impact of the geographic separation of command and control, compared to the effectiveness of the baseline model?	
Q1-4. If command and control were to be geographically separated, for which of the following functions do you consider that face-to-face contact (as opposed to VTC) between commander and staff is essential?	1. Personnel/Medical 2. Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) 3. Current Ops 4. Future Ops 5. Logistics 6. Communication and Information Systems (CIS)/Information Management (IM) 7. Targeting (Kinetic and Non-Kinetic) 8. Legal and Political Advice

[7] The CoNexus electronic voting system was used for this workshop. This consists of software and infra-red keypads.

	9. Media Ops 10. Civil-Military Co-operation (CIMIC)
Q1-5. Which combination of changes to the baseline model do you consider most feasible for Future C2?	1. No change – maintain baseline model 2. Reduce/remove componency 3. Compress Command 4. Geographically separate command and control 5. Option 2 and 3 6. Option 2 **and 4** 7. Option 3 **and** 4 8. Option 2 **and 3 and** 4

Table 3-1: Questions to elicit assumptions on the future C2 model

Block 2 Questions	**Voting options**
Q2-1. To achieve the necessary coalition, joint, cross-government, inter-agency interactions at the operational level, would the Future C2 model affect the number of specialists required or the range of specialisms?	1. No change 2. A change in the number of dedicated HQ specialists 3. A change in the range of HQ specialisms 4. A change in the number of dedicated HQ specialists and a change in the range of HQ specialisms 5. A change in the number of generalist staff who have a variety of skills and backgrounds 6. A combination of the above 7. Other
Q2-2. To achieve the necessary coalition, joint, cross-government, inter-agency interactions at the operational level, would the Future C2 model increase the need for civilians co-located in deployed HQs?	1. No – there would be less need than is currently the case 2. No – there would be no change from current assumptions 3. Yes – there would be an increased

Table 3-2: Questions to elicit assumptions on manpower implications

TEST STAGE

This stage takes the output from the workshop and tests the hypothesis that *"Adopting the proposed Future C2 model is better than maintaining the current one"*.

Interviews with relevant decision-makers identified that to test this hypothesis, a number of high-level questions would need to be answered. Four of these are:

- Q1: Is the proposed Future C2 model better in realising military effect than maintaining the current one?

- Q2: Will the future C2 model enable more effective/efficient delivery of our capability, and how will this impact on overall future force structures? In particular how will this impact on HQ and command structures?

- Q3: What is the impact of the proposed Future C2 model on manpower and training requirements?

- Q4: What is the impact of the proposed Future C2 model on the shape, number and priority of future communication, battlespace management, and ISTAR[8] equipment capabilities?

The complexity of these questions requires that a number of different methods are used, across the spectrum of human sciences research, operations research and experimentation. Three points are worth noting. The first is that the set of methods needs to range from detailed research on sense-making (at both the individual and cognitive levels) through to high-level force structure assessments. The second point is to note that only the first of the questions examines the impact of the new C2 model on operational effectiveness. For the other questions, it is assumed that it is better in operational outcome and the aim is to test whether it is better in terms of the resources (people and equipment) that are needed. The final point to note is that all questions will consider the UK operating in a coalition, multi-agency context.

A hierarchy of metrics will be used to compare C2 models. The highest will be Measures of Policy Effectiveness, such as the Whole Life Cost of the overall Force Structure. The next level will be Measures of Force Effectiveness, such as time to achieve campaign objectives and combat power losses. Below these will sit Measures of C2 Effectiveness, such as the accuracy of the operational picture (compared with ground truth) and responsiveness to requests for information.

This paper does not describe the full set of research, studies and experiments that will inform the answering of these questions. It provides four examples of the spectrum of methods that will be used; one example for each of the four questions. The paper then describes the approach that will be taken to try and establish an integrated, coherent programme across all of the work that will be carried out.

Man-in-the-loop wargaming is one of the methods that will be used to explore the impact of the proposed C2 model on operational effectiveness (Question 1 above). A study will be conducted using the WISE[9] formation level wargaming capability, which has been designed to allow assessments of C2 structures and processes. It allows representation of different levels of Shared Situational Awareness and can be flexibly reconfigured to represent any type of organisational structure, changing who commands or communicates to whom, and who has access to which resources or information. An organisation within WISE can be represented by its perception, decision making roles and behaviour, physical resources, and allegiances.

Spreadsheet modelling will be one of the methods used to test the impact of the proposed C2 model on force structure (Question 2 above). A study using the

[8] Intelligence, Surveillance, Target Acquisition and Reconnaissance.
[9] The Wargame Infrastructure and Simulation Environment (WISE) developed by Dstl

CHIMERA[10] model will explore whether the C2 model provides a more robust structure against future demands, with the same or less overall resource cost, than the currently planned structure. CHIMERA is a flexible and re-useable tool that has been in long-term use in informing future UK force structures. The model considers five sets of assumptions on force structure: the numbers and readiness profiles of each asset in the force structure, the set of assets required to undertake each scenario effectively, allowed asset substitutions, the cost[11] of each asset, and the combinations of scenarios that are to be tested. The model calculates the number of asset shortfalls and surpluses for each scenario combination, after all possible asset substitutions have been considered. If required, CHIMERA then rebalances the force structure, by using money saved by removing surpluses to buy more of the assets that are in shortfall.

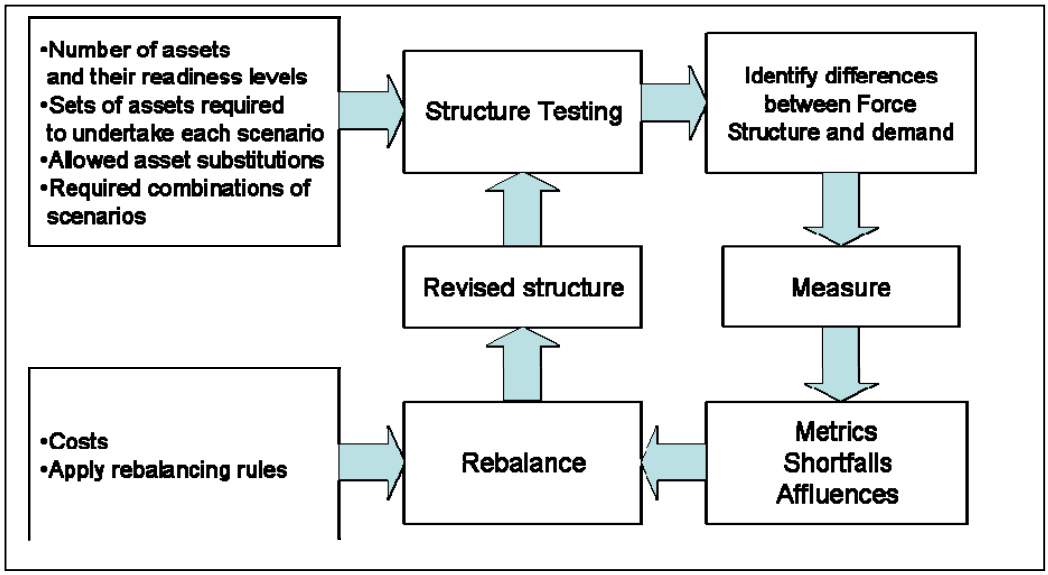

Figure 3: Schematic of CHIMERA analysis process

Human Sciences research will inform Question 3, on the manpower and training implications. Knowledge from such research will also inform on the cognitive and other human factors assumptions to be taken into wargaming, experiments and constructive simulations. Examples of issues that this human factors research is expected to inform include:

- Whether the risk of C2 failure has been altered through any potential human behaviour (at the individual or collective level) that may have been introduced or aggravated by the new C2 model.
- The implications for command, including in coalition operations, and hence on selection criteria and training needs.

Constructive simulation will contribute to testing the impact on future equipment capabilities and priorities. One of the methods that will be used has been successfully applied over the past few years to test the sufficiency of the UK's planned communications infrastructure in the light of demands placed upon it by ISTAR systems. The method has a number of steps as shown in Figure 5, and described

[10] CHIMERA (Combined Highly Integrated Method for Effectively Rebalancing Assets) is… *to be completed*

[11] In terms of Equivalent Annual Cost, a measure of the Whole Life costs of the asset.

below. The first step is the production of a mission chronology that provides a high level view of 'who was doing what and when' during a campaign. These are produced by extracting the detail from a run of one of the Dstl campaign models, CLARION[12] or COMAND[13]. This is only possible because the models are command and control led, with identifiable missions at all command levels. An estimate is made of the information loading that would arise during the campaign, through the use of Mission-based Information Exchange Requirement (IER)[14] templates that are derived from the business processes involved in planning and executing the missions. The ability of planned communications networks to support the desired information exchanges is then tested using a commercial model, GCAT[15]. This is a high level resource scheduling tool that is used to assess the performance of communication networks in a wide range of system configurations. To be considered successful a message must be delivered within its timeliness requirement. The final step in the method is to quantify the impact on campaign level measures of effectiveness. This is achieved using a mix of mission-level models and the high level campaign models.

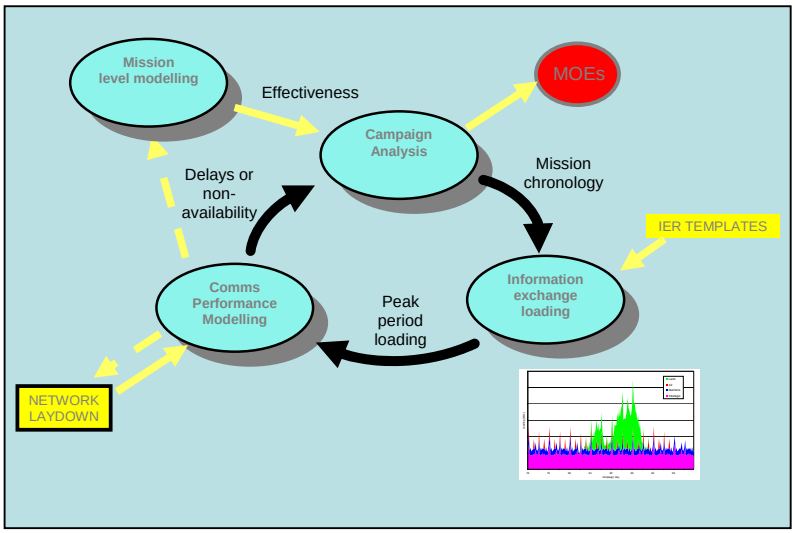

Figure 4: Method used to assess impact on C4ISTAR

<u>Creating coherence between the studies</u>

The most challenging aspect of the Test phase is to achieve sufficient coherence between each study and experiment, that the findings are collectively robust. Each study and experiment needs to understand how it relates to others in the programme,

[12] CLARION (Combined Land-Air Representation of Integrated OperatioNs) is a high level, fast running simulation of land/air combat at the campaign level that is driven by a command and control system.
[13] COMAND (C3 Oriented Model of Air and Naval Domains) is a monte-carlo simulation of joint and combined combat operations at the campaign level that is driven by a command and control system.
[14] Each IER captures the source(s) and recipient(s), its time into the mission, the reason for the exchange, the frequency with which it occurs per day, the preferred medium, the duration (for voice and videoconferencing) or size (for data and imagery) of the exchange, and the required timeliness.
[15] GCAT (Generic Communications Assessment Tool) has been developed and is used by QinetiQ.

and the data dependencies that exist between them. To aid this, it is planned to exploit work on the NATO C2 Conceptual Model [7]. This NATO model is in its early stages of development and validation, but it has published material a C2 Value View Value View that is described as the set of variables that "*both influence and are influenced by others and this describes the relationship between them*". Thus, this Value View will be explored to see whether it helps in creating the necessary visibility and understanding of 'data dependency' between studies.

CONCLUSION

This paper has described an ambitious programme of UK work to help inform MOD on whether it is possible, in the networked era, to enhance the Command and Control of expeditionary operations at the operational and tactical levels. The programme is in its very early stages. The Define stage, to create the set of assumptions for a Future 2 model, will have completed by the time of ICCRTS11. The Test stage, which applies a broad range of science to test the hypothesis that the new model is better than maintaining the current one, will have started during summer 2006.

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ACKNOWLEDGEMENTS

Colonel Nigel Beer (Dstl) for assistance with formal definitions and with review of the paper, Dr Tim Gardener for assistance in defining the Test phase of the approach, and Andy Caldwell for advice on CHIMERA.