ICCRTS 128
UK 07

2004 Command and Control Research and Technology Symposium

The Power of Information Age Concepts and Technologies

TITLE OF PAPER:

A conceptual model of organisational and social factors in Headquarters

Name of Author/Co-Author(s):
Graham Mathieson (Dstl) & Mrs Lorraine Dodd (QinetiQ)

Point of Contact:
Graham Mathieson

Organization:
Defence Science and Technology Laboratory, Ministry of Defence, UK
QinetiQ plc

Complete Address:
Dstl Portsdown West
Portsdown Hill Road
Fareham
Hants,
PO17 6AD
United Kingdom

Telephone:
+44 2392 217732
Fax:
+44 2392 229049

E-mail Address:
mailto:glmathieson@dstl.gov.uk

This paper is the 7th in a set of 13 presented to the 9th ICCRTS by staff of the Defence Scientific and Technical Laboratory (Dstl) and QinetiQ plc, relating to ‘command in the network enabled era’. The papers are based on research undertaken for the United Kingdom Ministry of Defence’s ‘Network Enabled Capability’ programme and,

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2004**	2. REPORT TYPE	3. DATES COVERED **00-00-2004 to 00-00-2004**
4. TITLE AND SUBTITLE **A conceptual model of organisational and social factors in Headquarters**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Defence Science and Technology Laboratory,Dstl Portsdown West,Portsdown Hill Road, Fareham,Hants, PO17 6AD United Kingdom, ,**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**41**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

9th International Command and Control Research and Technology Symposium

A Conceptual Model of Organisational and Social Factors in HQ[1]

Graham Mathieson
Defence Science and Technology Laboratory
Dstl Portsdown West, Portsdown Hill Road, Fareham, Hampshire, PO17 6AD, UK
Tel: +44(0)2392 217732; Fax: +44(0)2392 217449
glmathieson@dstl.gov.uk

Lorraine Dodd
QinetiQ, Malvern Technology Centre
St. Andrews Road, Malvern, Worcestershire, WR14 3PS, UK.

This paper is the 7th in a set of 13 presented to the 9th ICCRTS by staff of the Defence Scientific and Technical Laboratory (Dstl) and QinetiQ plc, relating to 'command in the network enabled era', based on research undertaken for the United Kingdom Ministry of Defence's 'Network Enabled Capability' programme.

ABSTRACT

The potential of Information Age technology to support collaboration at a distance invites military forces to create agile mission groups, which can form, adapt and re-form rapidly and sympathetically to changing circumstances. Managing such an agile capability will require agile headquarters, as part of a wider Information Age Command and Control concept. This paper explores the implications of HQ agility from the stand-point of organisational and social science, and presents the results of thinking about how organisational and social factors can be integrated into modelling.

The paper draws from social and organisational science literatures, C2 experimentation, and modelling research, to map out the key factors impacting on the relationship between capability investment and HQ performance and behaviour. It outlines a revised conceptual model capable of addressing a requisite subset of variables and bringing them together into a coherent model implementation. The model requires a judicious synthesis of approaches, striking a practical balance between detailed and abstraction.

The paper draws encouragement from existing model implementations, but the synthesis of a requisite model remains a challenging task. Success will allow analysis to support an integrated approach to investment in Network Enabled Capability (NEC). Failure has significant implications for acquisition justification and management.

1. Introduction

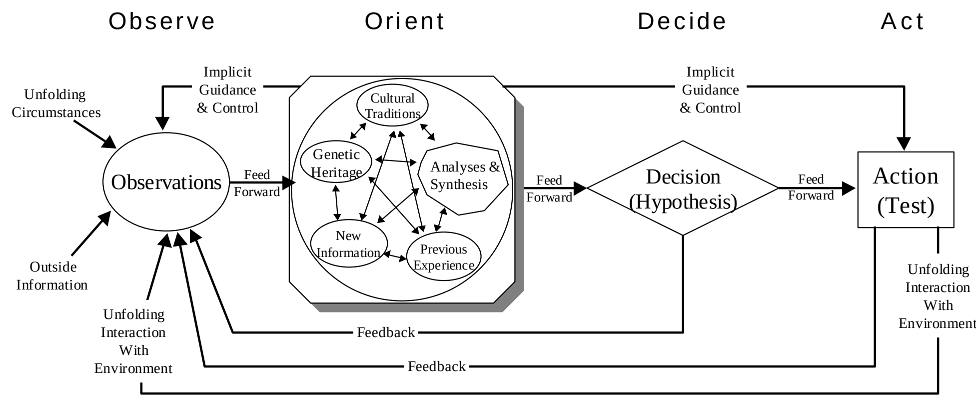
The potential of Information Age technology to support collaboration at a distance invites military forces to form, adapt and re-form mission groups rapidly from a pool of capability elements, in response to changing mission demands and circumstances. Assuming that force commanders are not willing to allow agile mission grouping to arise entirely from self-organisation, i.e. with no direction, then it will need to be managed by agile[2] headquarters (HQ) organisations, as part of a wider development of Information Age Command and Control (C2) concepts [Alberts, et al, 2001].

There is a widespread belief in Defence communities that the potential offered by Information Technology (IT) is best realised by emphasising the role of information in supporting human decision-making. The Digitisation programmes of the 1990's were founded on the expectation that getting the 'right information to the right person at the right time' would dramatically improve military effectiveness. This idea is taken forward into the era of Network Enabled Capability (NEC) [MoD, 2001] and Network Enabled Operations [Alberts, et al, 1999], but is expressed from the viewpoint of shared information supporting shared understanding (by decision-makers) and synchronised action, again promising to achieve dramatic improvements in military effectiveness.

However, much that is written about the impact of information on human decision-making and, hence, group behaviour is naively simplistic and liable to mislead those who seek to make balanced and effective investment in military capability. Human decision-making is a complex affair, depending on a wide variety of factors including, but not limited to, information, personality, experience, emotion, and context [Sheppard, et al, 2000]. Furthermore, research into so-called 'naturalistic decision making' (NDM), exemplified by the work of Klein and Rasmussen [Klein, et al, 1993], suggests that it is normal for humans to generate actions without explicitly formulating or choosing between options, i.e. without making 'decisions' in the strict meaning of that term.

Interestingly, the ubiquitous OODA Loop, or Boyd Cycle[3], which is often referenced in support of an information-driven view of C2, contains within its original formulation social, cultural and genetic factors as equal partners to information, as illustrated in Figure 1 [Boyd, 1996]. The figure also shows how Boyd recognised the existence of 'implicit guidance and control' mechanisms which can allow directed action to arise without explicit decision-making. Indeed, Boyd suggests that most people, most of the time do not make decisions but go directly from observation to action, with explicit decision-making mainly required to facilitate co-ordination between multiple people [Boyd, 1992].

[2] Agility in the context of this paper includes adaptability, flexibility, responsiveness, robustness, innovativeness, and resilience as defined by Alberts and Hayes (2003)
[3] The OODA Loop (Observe, Orient, Decide and Act) was formulated by the late Colonel John Boyd of the US Airforce and is probably the most widely referenced construct in C2 analysis.



Note how orientation shapes observation, shapes decision, shapes action, and in turn is shaped by the feedback and other phenomena coming into our sensing or observing window.

Also note how the entire "loop" (not just orientation) is an ongoing many-sided implicit cross-referencing process of projection, empathy, correlation, and rejection.

From "The Essence of Winning and Losing," John R. Boyd, January 1996.

Figure 1: The Boyd Cycle or OODA Loop, as expressed by Boyd himself.

An understanding of the mechanisms whereby people, including highly trained military commanders, interact with their environments and generate behaviour is vital to any rational approach to investment in C2 capability, including IT. Nor is this need limited to humans as individuals. Similar 'natural' mechanisms of behaviour generation exist in the humans groups and organisations, including highly professional, task-oriented organisations such as a military HQ.

In particular, the ability of an HQ to be agile depends upon much more than shared understanding arising from information sharing. A wealth of scientific literature and military experience supports the fact that a typical HQ is a complex, socio-technical system in which significant factors arise not just in the physical and informational domains, but also in the cognitive and social ones. Understanding the response of an HQ to interventions, such as the introduction of IT or other measures to improve agility, requires a comprehension of the multiple "dimensions" of human variability.

These "dimensions" manifest themselves in the form of overlapping and interconnecting structures that provide a constraining "logic" within which the HQ has to perform its function. If the HQ is to be agile then the interlocking mechanisms need to be made explicit so that the way to unlock and reform them can be represented and understood as one of the formal C2 processes. It may be easiest to view the interlocking logic locally (around the nodes of the structure that needs to be adapted) as a dialectic but with full knowledge of the "knock-on" effects of any adaptation in terms of constraints, shared utility and beliefs about future outcome. For example, certain dialectics exist within peace-enforcement operations when forces on the ground rely on the same physical infrastructures (such as electricity, water, roads, etc) and need to preserve particular social structures (such as those defining authorities, responsibilities, competencies, etc) and certain belief systems that reside within them (defining trust relationships, etc).

This paper explores the implications of HQ agility from the standpoint of organisational and social science, and presents the results of research into how organisational and social factors can be integrated into the modelling and analysis used to support assessments of military capability investment. Drawing from a wide base of social and organisational science literatures, the results of recent military C2 experimentation, anecdotal evidence from recent operational experience, and lessons learned from advanced modelling research, the paper maps out key factors which may impact on the relationship between investment in HQ capability and the resultant performance and behaviour. The research reported here exploits and contributes to a NATO research group (SAS 050) which is seeking to construct an improved conceptual model of C2 as a whole.

The paper first discusses the current state of knowledge concerning organisational and social factors relevant to HQ performance and behaviour. It then describes some of the interim results of the conceptual modelling work of the SAS-050 group and UK modelling research, which is seeking to build a more effective conceptual model of an HQ. Finally, the paper discusses how such a conceptual model might practically be implemented in a simulation suitable for operational analysis (OA), and the implications for the NEC capability acquisition process of a failure achieve a requisite implementation.

Throughout the paper a (seemingly) simple case study is used to provide a tangible illustration of the ideas discussed. This case study is briefly presented below.

2. **Case Study for illustrating issues**

The implementation of NEC presents a wide range of issues for which an understanding of social and organisational variables will be essential to effective investment. However, we have identified that even apparently simple interventions can require a rich, multi-dimensional model to make sense of likely consequences.

One straightforward option for HQ capability arising from the potential of IT is 'reachback'. Reachback can take many forms, but the one presented here was used to test the developing conceptual model and gaps in its coverage. The following brief description will form a context in which to make the generalities of the conceptual model more specific and tangible.

Fielded HQ's typically suffer limitations in their ability to access and synthesise knowledge derived from out of theatre. This is particularly important in expeditionary operations with a strong diplomatic as well as military content. There are also perceived issues about the speed of deployment, mobility and protection of HQ's numbering hundreds of personnel. The Army is considering the possibility of exploiting Information Age technology to allow it to place the bulk of HQ personnel in the rear, where they can be provided with more secure and effective broadband communication networks and easier access to wider knowledge networks. This would leave only a small core command cell forward deployed to provide local situation awareness, command and leadership.

The rear element would probably comprise the bulk of HQ staff functions and would operate from a fixed base with well-established infrastructure. The forward element would comprise all of the necessary command and control functions but each probably represented by only one or two officers who would use reachback to obtain staffing services from the rear unit.

The expected benefits of such an arrangement would be a smaller, more agile forward element and a better access for the staffing functions to knowledge and expertise available in the wider Defence networks without consuming as much limited SATCOM bandwidth.

Potential negative effects of the creation of a rear staff unit could be a loss of coherence between the deployed and rear element of the HQ, affecting awareness and performance, and possible impacts on motivation and participation.

Three "options" for reachback are considered:

- No reachback - full HQ co-located in theatre;
- In-theatre reachback - Core HQ deployed forward with staff unit in rear of theatre;
- Homeland reachback - Core HQ deployed forward with rear unit at a home base.

In the context of the HQ modelling research reported here, this case study proved a major factor in determining the requisite dimensionality of the conceptual model. For the present paper it will be use as context for some of the discussion.

3. **Current Knowledge**

The scientific disciplines necessary for effective analysis of socio-technical systems are not a coherent body of knowledge. Even within quite narrow swathes, the individual disciplines form a loosely coupled construct. Disciplines like organisational theory, information theory and cognitive psychology, all essential sources for OA, weave around each other like the ropes in a knot, rather than fully integrating. They overlap within the same real world 'space', but their theories and understandings are only tenuously linked.

This means that the analysis of the OA practitioner becomes limited by the fidelity of the individual strands of theory and by the extent to which the strands provide a complete and consistent coverage of the real-world issues being studied.

Sometimes this is not a serious problem. If the question at hand is of a more abstract nature, such that the inferences required of the model arise from macro structure, then the individual knots binding one area of theory to another can be allowed to slip below the level of scrutiny, while the OA practitioner stands back and looks at emergent patterns. The connections between scientific disciplines become like the knots in a fishing net or a fine lace, defining the structure of the whole, but not the chief focus of appreciation [Mathieson, 2003a].

This may be the case for some high-level OA studies, but it is most certainly not the case for a system level study in which the intervention being considered impacts within the HQ itself. In the context of the Reachback Case Study outlined above, the broad range of scientific disciplines involved in a requisite conceptual model becomes clear. Table 1 shows a sub-set of the variables and relationships which would need to be understood in order to discriminate and assess the effectiveness of the case study options (described earlier). Alongside each we identify the range of human science disciplines that are important to understanding the factors, and discuss some of the things already well established in the literatures of those disciplines.

Factors and relationships	Relevant human science disciplines
Co-location of HQ staff and its impact on teamworking	Various social network theories provide explanations for how team members will tend to work more or less closely with each other. Organisational psychology can describe the effects of social interaction (affected by co-location) on trust between team members.
Use of computer-mediated communications networks and its impact on understanding and trust	Cognitive psychology and expertise from human factors integration can together explain how communicating task information via computer screens produces different levels of understanding, trust and acceptance when compared with face-to-face meeting.
Organisational scale and its impact on process and structure	Organisational theory describes how the number of people in an organisation is linked to levels of formality in their mechanisms of interaction and, hence, to the reliability and agility of processes.
Leadership and its impact on participation and morale	Teamworking research provides insights into the roles and impacts of leaders in teams, including links to team cohesion and team spirit. Psychological research can provide understanding of how commitment to task, willngness to take risks and general morale are related to the nature of leadership exercised within a team. Social psychology can also provide insights into the how groups of humans provide (or fail to provide) mutual support within groups, and how perceptions of group membership impact on commitment to task.
Use of IT and its impact on participation in decision-making	Organisational studies have shown how the extent and depth of particpation in decision-making by organisation members relates to the extent of use of technology-based information services.
The relationship between formal roles structures and team behaviour	Organisational studies and operational research clearly show that people do not slavishly follow formally declared processes and structures. Even in strongly formalised organisations people adapt their behaviours in response to the needs of their situation and a variety of informal goals and objectives.

Table 1: An illustration, based on the 'Reachback' case study, of some of the significant factors and relationships relevant to the study and the range of human science disciplines needed to provide the insights and understanding necessary for effective assessment and discrimination of the options.

Much of the knowledge needed to understand how an organisation, such as a HQ, will respond to investment in its capabilities is already well established, and the knowledge base is rapidly evolving in the face of Information Age challenges.

Groth (1999), for example, has adapted the seminal work of Mintzberg (1979) to provide a convincing analysis of how IT removes some, but not all, of the constraints that shape organisational forms. He identifies a range of new possibilities, but also emphasises those constraints that arise from unchanging aspects of the human condition. For example, Groth suggest that the speed and volume of information exchange between humans is not the principle advance of the Information Age because, however capable the IT may be, the human capacity to absorb and process information is largely unchanged. Rather, Groth suggests the ability to achieve co-ordination through parallel and asynchronous access to common databases has the more impact in creating new opportunities for organisational development and the capacity to undertake larger and more complex tasks.

Kiryakidou (2002) describes the beneficial effects of close social networking on the sharing of relevant task information, but also highlights parallel negative effects in which strong ties between team members can reduce the total amount of information exchange and inhibit the generation of novel views.

There are other factors, which are not significantly changed by the advent of the Information Age, but which come in to play in the organisational response to it.

Human organisations tend to be conservative in nature, resisting the imposition of new processes and structures, and recovering familiar ones through informal networking. Attempts at Business Process Re-engineering (BPR), popular in the latter half of the Twentieth Century, largely failed to achieve lasting change. Most organisations involved reverted to previous forms and processes after a few years. The reason lies in the failure of business managers to adequately account for the powerful social and organisational forces involved [Avery, 2003].

There is no reason to suppose that such forces are not present even in highly disciplined military organisations; indeed much anecdotal and some experimental evidence suggests that they do. The implications for the concept of agile mission grouping are clear and serious.

For an organisation to be effective, it is important to ensure that the structure that defines the responsibility hierarchy is aligned with and strongly corresponds to that which defines the authority for action. Competency also needs to be addressed and aligned to take into account the important issue that people are being asked to work within their "comfort zones" of expertise and experience. The experience of the Canadian Airborne Regiment in Somalia highlights the implications of non-aligned chains of command. [DND, 1985a, 1985b, 1988]

The British Army previously used functional structures to define and clarify C2 arrangements to cope with the multi-tasking aspect of military forces while maintaining the divisional structures that are necessary for the resource support, administration and management for each force element. For example, fire support elements under responsibility of the Artillery Commander are placed under the command of a Brigade commander explicitly for the function of providing Fire Support. The fire support elements can be assigned according to "service level agreements" that range between being a unique allocation "in direct support" to being temporarily allocated "on-call" and each of these levels has a well-understood responsibility for provision of equipment and authority to issue commands.

There will be different degrees of mutual benefit gained from allocation within a functional C2 arrangement. This demands different "binding" relationships ranging, for example, from co-operative accountability to full contractual agreement.

If we are to represent in our simulations varying degrees of sharing information, beliefs, values and priorities, then we must be able to decompose these within the C2 representations [Dodd, et al, 2004]. Using these new constructs it is possible to investigate the effects of isolation and interaction through shared or inherited values and beliefs in terms of the decision outputs. The decision outputs will change (even though the content and nature of the information inputs remain unchanged) due to environmental changes embodied in the C2 arrangements, objective priorities and anything that perturbs the "comfort zone landscape".

Recent experimental work [Mathieson, 2001 and Malish, et al, 2003] has clearly demonstrated that variations in the course of action chosen by military commanders may owe as much to internal moderators such as personality as to variations in the availability and quality of situation information. This insight is important if we are to use modelling to assess the extent to which investment in information services impacts Command effectiveness.

Recent research to extend the existing Rapid Planning process [Moffat, 2000] (that forms the basis for modelling C2 agents in some UK simulations of military operations) used some of the experimental gaming results to explore the effects of conflicting objectives within C2 structures.

The UK research from which the present paper has emerged [Mathieson, et al, 2002] has sought to synthesise a wide range of well established, but previously disconnected, areas of current knowledge to create a requisite conceptual model. The goal is a model able to explain the impacts of a variety of psychological, organisational and social variables on HQ behaviour and performance. Work is ongoing, but the emergent conceptual model is reported below. Although focussed on the psychological, organisational and social factors relevant to an HQ, the UK work has exploited and contributed to a wider synthesis being constructed by a NATO research group (SAS-050).

4. NATO SAS050

The Studies, Analysis and Simulation (SAS) panel of the NATO Research and Technology Organisation has sponsored a research group, SAS-050, in order to:

- Develop a Conceptual Model capable of exploring the properties and the advantages / disadvantages of new command concepts
- Assemble a Tool Set capable of supporting exploratory analysis
- Apply the Conceptual Model employing the tool set to explore a set of issues related to new command concepts
- Provide for Peer Review of the Conceptual Model and its application
- Document Conceptual Model, Tool Set, Measures, and Lessons Learned

The conceptual model emerging from this international collaboration emphasises the need for multiple viewpoints to properly capture the concepts needed. The model, as currently conceived, is built upon a network of variables and comprises a value view (expressing measures of merit) and process view (expressing process, organisation and social variables). Following the ideas in the NCW conceptual model [reproduced in Holt, 2003], the variables are categorised using the physical, informational, cognitive and social domains. The model also seeks to express the complex time dynamics involved in C2 by using a state-transition construct in the process view overlaid with a more abstract temporal dynamics view.

5. Building the conceptual model

It would be presumptuous to believe that all of the individual, organisational and social factors relevant to an agile HQ can be captured, even abstractly, in a practical simulation model. However, in order to understand and mitigate the limitations of our simulations and assessment studies, it is necessary to have a requisite conceptual model of any particular problem to be studied. In this section, we will present the interim results of research seeking to construct a composite conceptual model capable of explaining the range of variables and relationships discussed above and of representing their effects with a fidelity suitable to facilitate system level OA. In a later section we discuss a proposed practical implementation of the model, including a treatment of the problem of data.

The key to an effective explanatory model is that its core architecture captures the essential concepts of that which is modelled. We begin, therefore, by describing the essence of a military HQ not as a task organisation, nor as a decision-making entity, but as a human enterprise. Like any other human enterprise, the HQ is a complex, socio-technical system with many dimensions and facets. While the task undertaken by the HQ is important to consider, it does not define what the HQ is, nor does it fully explain variability in its behaviour and performance. A requisite conceptual model also needs to explicitly deal with variability arising from human agency and individuality, teamworking, organising, socialising, and the fact that the HQ is self aware and reflexive. In addition, in some circumstances, the model may require a representation of self-organisation and emergent properties.

Representing the HQ task

Since processes and procedures are themselves variable within an agile HQ, the conceptual model cannot define them in detail. Instead, we propose a task representation operating as a more abstract level, similar to the mission-oriented approach adopted by UK high level combat models [Moffat, 2004]. Under this approach, the HQ task will be defined as a set of activities, which are performed to achieve products, while consuming resources (time, effort, consumables, etc.). While the activities themselves are generic, the exact sequence, duration, and performance of them will depend on the resources carrying them out, as well as on the context.

More detailed procedures for executing task activities are provided in the conceptual model by teams of human agents, based on knowledge of organisational goals, operating procedures and the task context. In this way, the conceptual model will be capable of describing the mechanism by which different teams (and the same team at different times) may vary and adapt procedures for the same apparent task.

Representing individual agents

The activities of the HQ are performed by human agents, usually operating in teams. The future possibility of significant use of artificial agents to perform HQ tasks is recognised, but not considered further in this paper. The term 'agent' in this context is used to indicate agency or self-directed behaviour. For system level studies the agents will need to be represented as rich and sophisticated entities with many parameters and internal relationships. Agent-based modelling of the sort represented by the MANA or Socrates models [Engleback, 2003][Sheldon & Upton, 2003] would not be appropriate here. However, the conceptual model needs a mechanism to allow for the moderating influence of the task context and the wider network of interactions between agents.

Our proposed conceptualisation of individual agents is designed to allow for variability between individuals and for individual adaptation over time. Key components of the individual agent needed to explain such variability include:

- The role of framing in situation understanding, decision-making and action;
- The role of memory and learning in expertise and adaptation;
- The role of emotion and sub-conscious cognition in higher reasoning;
- The role of personality and pre-disposition in shaping behaviour.

We have taken the idea of agent 'frames' from the work of Klein (1997), although it is present in the work of other authors. The agent frame comprises the set of knowledge and mental models constructed by the agent in response to the situation. The term 'constructed' is important here. Agents have various types of knowledge with which they construct mental models of their situation and procedures for action. In Klein's conception the frame acts in two roles. It represents the world-view of the agent and it also acts as a sense-making filter on new perceptions.

Agent frames will also contain a reflection of organisational and social context. The agent's understanding of their role(s) and their expectation of others will affect the interpretation of situation information and shape the space of conceivable action. Viewed over a longer timeframe such social sensitivity manifests itself as recognisable pre-dispositions and tendencies we associate with Culture, in all its various guises.

The role of memory is critical to understanding agent behaviour. Human cognition operates principally with working (or short term) memory, which is a very limited resource. Long term memory is used to provide a knowledge repository, probably stored as networks of related fragments from which what we recognise as memory is constructed. Thus, memory is not mere re-call but a re-modelling of the world based on relationships to present stimuli, and coloured by more recent experiences. Viewed from this perspective, learning is achieved by laying down new relationships between existing fragments of knowledge and, more rarely, new knowledge fragments.

Due to the severely limited capacity of cognitive working memory, humans have evolved rich strategies for managing complex behaviour. These involve a heavy use of sub-conscious cognitive processes operating at all levels up to, and including, higher reasoning. People are largely unaware of their cognitive processes and, when asked to explain decisions or behaviours, will construct explanations based on a combination of reconstructive memory, story-telling and educated guesswork. The conceptual model of decision-making, therefore, cannot be based solely on the self-report of decision-makers, even very experienced and reflective ones.

At a deeper level, both memory and learning are probably related to forming and atrophying of networks of neural connections, and non-cognitive processes such as affect and environmentally sensitive biochemistry can influence this physiological process. Higher phenomena such as belief, trust and commitment to goals are likely to be closely linked, via memory and learning, to affective phenomena, as evidenced by clinical studies [Carter, 1998].

Since the vast majority of the knowledge used by agents to guide current actions has been recovered from long term memory, it is important to understand what longer term influences, remote from the current situation, can find expression via this mechanism. Experimental studies [Mathieson, 2001] [Malish, et al, 2003] have demonstrated that personality plays a major role in what military commanders choose to do. Indeed, the experimental results indicate that variation in personality may be at least as important in explaining command behaviour as improvements in the availability and quality of situation information quality likely to arise from NEC. It is possible that these effects arise through the process of laying down networks of knowledge relating situation cues to pre-learned actions, which latter are recovered through NDM recognition strategies.

A combination of physical, informational, cognitive and social mechanisms is needed to provide a requisite conceptual model of human agent behaviour. The OODA model described by Boyd (see figure 1) is an attractive option for representing this synthesis of dimensions. However, Boyd's model places the focus on the process by which action is generated, whereas the present conceptualisation is more interested in the processes through which variability arises, since these are the ones upon which agility depends, and by which it is constrained.

In the HQ context most tasks are carried out by teams of agents, who are co-operating to a greater or lesser degree. The conceptual model, therefore, needs a representation of teams and teamworking.

Representing teams of agents

The agile HQ will depend upon an ability to dynamically form teams in response to changing task and resource drivers. Thus, the conceptual model must represent the processes of team forming and re-forming and their impact of this on task work. A well-established conceptualisation of team dynamics is the forming, storming, norming, and performing process. This process is a useful framework to explain the relationship between teamworking and taskworking. The further through the process a team is the less of their collective resource needs to be spent on teamwork and the more can be devoted to task work, with a consequent increase in efficiency and, all other things being equal, performance.

To understand where, within the process, a team is likely to be, and how long it will spend in each stage, we return to the concepts of frames and knowledge. The research work of Noble (2003) has successfully use an analysis of the knowledge held by team members to diagnose the causes of team behaviour and performance. Noble identifies twelve knowledge enablers (categories of knowledge a team needs to have to operate well), which are shown in Table 2. Each category is related to different behavioural phenomena or pathologies, which arise when there are knowledge deficits.

Knowledge Enabler	Definition
Goal understanding	Knowing what the customer wants
Understanding of roles, tasks, and schedule	Knowing who's supposed to do what and when, and with what information and resources.
Understanding of relationships and dependencies	Knowing how entities, events, and tasks impact the plan.
Understanding others	Knowing what other team members' backgrounds, capabilities, and preferences are.
Understanding of team "business rules	Having and knowing effective and agreed upon rules for team members interacting with each other.
Task skills	Knowing how to do one's assigned work.
Activity awareness	Knowing what others are doing now and current need for doing it.
Understanding of the external situation	Knowing status of people (including client), things, and events of the world outside of the team and projecting future changes.
Current task assessment	Keeping tasks on track, knowing how well own and other's tasks are progressing, and when to offer help.
Mutual understanding	Knowing what other team members understand now and knowing if they agree or disagree.
Plan assessment	Predicting whether the plan will still enable the team to achieve its goals.
Understanding of decision drivers	Judging and applying the criteria for selecting an action.

Table 2: Noble's Knowledge Enablers, representing categories of knowledge needed by a team to operate effectively. Deficits in knowledge can be associated with performance and behaviour problems.

Knowledge in different categories can be acquired through different processes. For example, knowledge about other team members, which is major component of trust, is acquired through previous contact, by working together on the current task, and by social contact outside work. People will also use categorical associations derived from cultural understanding to fill gaps in such knowledge. For example, understanding this range of knowledge generation mechanisms would help us to discriminate the co-located and remotely networked teams in the Reachback case study. Remote teams are likely to have more difficulty in acquiring interpersonal knowledge and, hence, building trust. It may also be reasoned that a team lacking interpersonal knowledge will find it more difficult to establish team roles (as required by the 'storming' phase of team building) and the normal rules of business (as required by the 'norming' stage).

Many of the other knowledge categories defined by Noble can be similarly related to team building stages and we propose using this association as the basis for linking a variety of social and organisational processes, which generate various classes of knowledge, to teamworking and, thence, task performance.

It is likely that some useful abstraction of knowledge will be possible with parameters, such as coherence of knowledge, which relate to the team as a whole rather than the individual members. For this reason, amongst others, we propose to introduce a team frame, similar to the agent frames, with which to represent team related knowledge and emergent properties best described as relating to a 'team mind'.

Figure 2 illustrates the concepts of agents, frames, and teams discussed above. The figure also shows how some relationships between team members will need to be treated with higher fidelity. These include physical interactions (e.g. co-location) and communications. The latter needs to be made explicit to allow for differences in IT to be explicitly represented. Other interaction between team members, such as the social effects of working together, can be dealt with more abstractly.

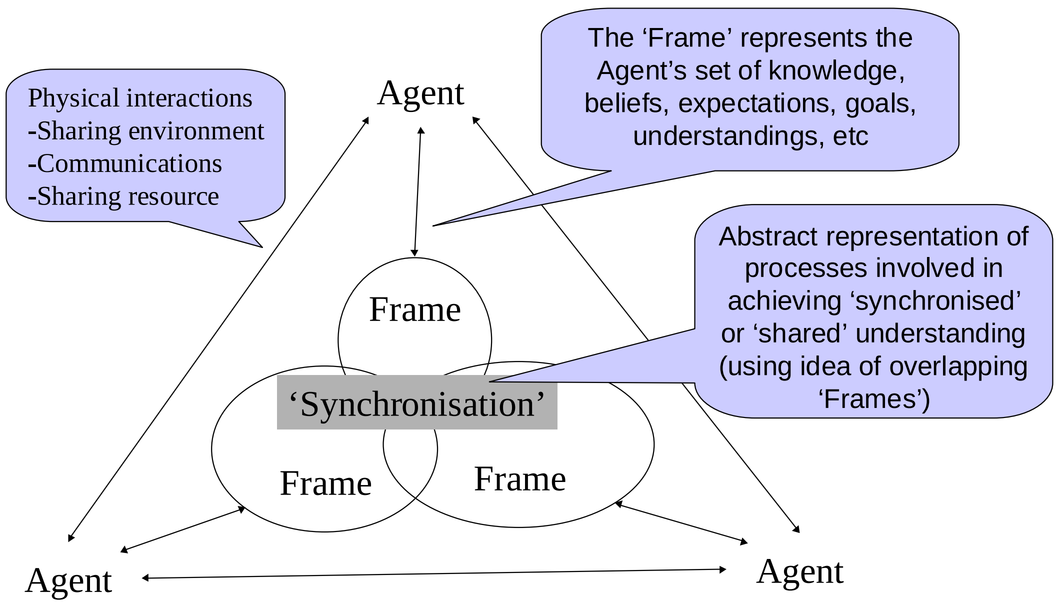


Figure 2: Illustration of the conceptual model of agents, with frames, interacting in a team. Note that some agent interactions will require more explicit representation because they are a key focus of attention, while others can be treated more abstractly via a notional 'team frame' which represents the synchronisation of agent frames to produce the effect of a single team mind.

On a wider scale, non-task-related social interactions between members of HQ as a whole will have an effect on the initial knowledge of team members, and ongoing knowledge acquisition.

Representing social processes

In an agile HQ task teams may be formed and re-formed dynamically. A key difference between this and a more conventional HQ lies in the level of prior knowledge of team members about each other and about the business rules under which they are to operate. Another of the key implications of the Information Age HQ is the possibility to form up HQ capability without necessarily co-locating HQ personnel. Therefore, the possibility of different levels of interpersonal knowledge between team members needs to be accounted for in the conceptual model. Such knowledge is best derived from previous experience of working with people, but this can be reinforced and supplemented by sharing non-task-related activity such as off-duty socialising. The ability to work together effectively can also be influenced by cultural affinity, a point particularly relevant in joint and coalition operations.

However, it is likely to be impractical to seek an explicit representation of social interactions across all potential team members. We propose a more abstract representation of socialising in which group level factors, such as resource sharing, cultural affinity and shared organisational history determine the initial interpersonal and business rules knowledge for the newly-formed team. The same factors will also influence the speed with which the team passes through the team forming stages.

Representing organisation

If the HQ conceptual model is to be able to capture agile team forming, then it will need to represent the organisational processes involved in managing agility. A representation of organisation will also be needed to provide a context for teamworking and social interaction. We propose to conceptualise organisation as the forming of interacting sets of relationships between agents and resources as indicated in Figure 3. The processes involved in organising will change these relationship networks. The networks, in their turn, will influence teamworking.

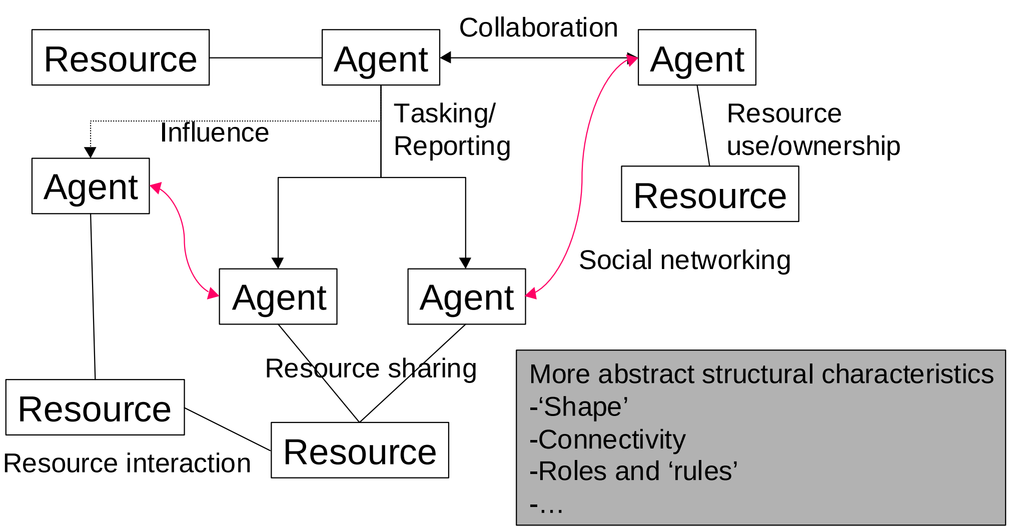


Figure 3: Conceptualising organisation as a set of relationships between agents and resources, plus more abstract structural characteristics. Organisational management and adaptation is represented as changes to the overlapping networks of relationships.

Representing self-awareness and reflexive behaviour

Human organisations behave differently from mechanical system because they are self aware and able to respond not only to actual changes but also to perceptions of change, whether real or imaginary. The effect of perception and reflexive behaviour may be particularly important in situations where participants are less familiar with each other and more likely to have false perceptions and mistrust.

The conceptual model, therefore, will need constructs to represent self-awareness, providing paths of influence from task performance and organisational change variables back into the social and teamworking processes. Our thinking in this area is not yet mature enough to make clear proposals for the conceptual model.

Integrating the conceptual model

Integrating the various conceptual views discussed above presents a significant challenge. Figure 4 illustrates how we plan to tackle this challenge, although much of the detail is still work in progress.

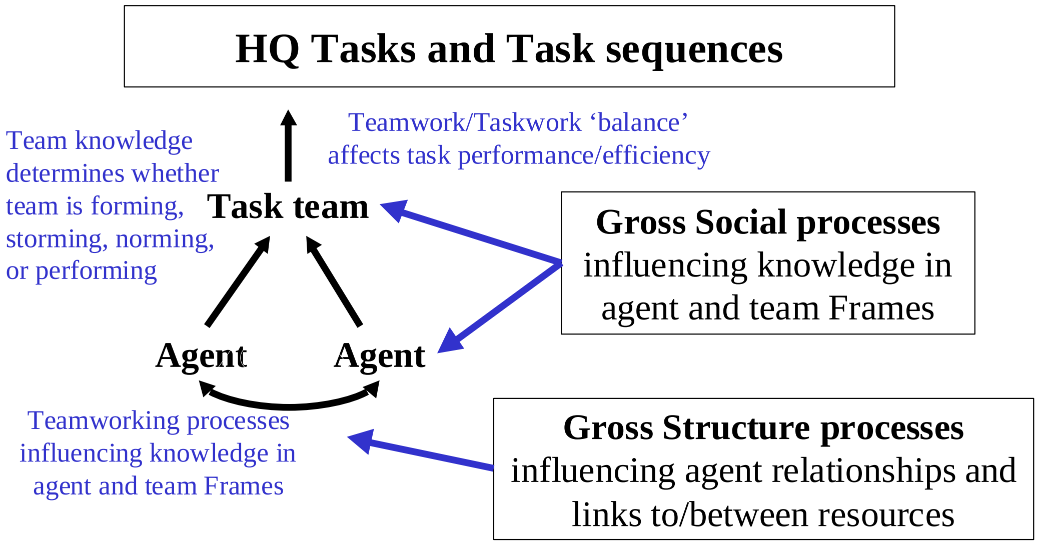


Figure 4: Illustration of the strategy for integrating the various views within the conceptual model.

Agents will be formed together into teams by a gross structuring process, which will set up relationships and provide links to resources. Teams will be initialised with knowledge from agent frames, which will be influenced by explicit teamworking processes and gross social processes. Teams will mature through the forming, storming, norming, and performing process, depending on knowledge acquisition. The relationship between team maturity and taskwork is based on the premise that teams need to divide their resources between taskwork and teamwork activities. Hence, task performance/efficiency will be moderated by team maturity. Agents and team will also bring specific data and functions to instantiate the generic activities in the task model.

The conceptualisation described above is rich and complicated. It might be thought to be over-complicated, but even a cursory consideration of the Reachback case study described above suggests that all the dimension currently included are necessary to construct a requisite model of even this apparently simple problem. Broader problems associated with NEC and NCO are unlikely to be simpler.

Implementing such a rich conceptual model will be challenging, and some consideration is given below to practical simulation methods, which are being considered in this ongoing research.

6. **Practical simulation methods**

A practical implementation of the conceptual model will require a judicious integration of different modelling approaches designed to strike a balance between detailed representation of processes and networks and a more abstract representation of emergent properties and behaviours. For example, the conceptual model seeks to explicitly represent the impact of investment in information and communication services on HQ team interaction, but assumes that the impact of HQ social processes, which also impact on team behaviour, can be represented more abstractly.

In this section we discuss practical approaches to implement the taskwork, teamwork, which we believe may allow us to successfully capture the richness and diversity of variables identified in the research which has led to the development of the conceptual model presented here.

The core of the conceptual model is the representation of teams of agents. It seems clear that this aspect would be best implemented using object-oriented techniques in which object data sets are used to implement the knowledge in agent frames (although some classes of knowledge may be best implemented as algorithms in object methods). Since the conceptual model seeks to represent teams as entities in their own right, we propose to instantiate team objects as the executors of tasks.

The task model could be represented using process-modelling techniques. A practical implementation of process and team structure adaptability has already been demonstrated using a modified version of a major HQ model based on Petri-Net techniques [Gott, et al, 2003] [Mathieson, 2003b]. This work has demonstrated useful variability, which is being used to support equipment capability studies. However, since the conceptual model conceives of a set of task with transition logic but no pre-defined task sequences, it may be more effective to use a finite-state transition model, analogous to the mission-oriented approach used in UK high-level combat models [Moffat, 2004].

For both the organisation and social process elements of the model and obvious candidate might be social network modelling, which is widely and successfully used in the social science community. The network technique, however, implies a reliance on generating gross properties by emergence form many agent-on-agent interactions. Since the conceptual model envisages a more abstract representation of social processes, an implementation based on mathematical algorithms might prove more practical.

We are currently seeking to incorporate all of the elements identified in the conceptual model within a single simulation, but recognise that there are alternative approaches, including a federation of simulations.

One major determining factor on the type of simulation technique will be the availability of data. Each modelling technique requires different types and formats of data. For example, a social network model will require parameters to shape interpersonal relationships, while an algorithmic approach may be able to use aggregate statistical data or more abstract parameters.

Acquiring reliable data for human and organisational modelling is very difficult and it is highly unlikely that the needs of the rich model envisaged here could be fully met at a reasonable cost. However, it would be inappropriate to build a non-requisite model just to avoid gaps in data availability. A better approach would be to build the requisite model and then treat parameters for which data is not available as uncertain variable, to be subjected to sensitivity analysis. This is the approach we intend to take.

7. **Implications of success (or failure)**

Successful construction of a requisite conceptual model, especially with a practical implementation, will allow us to support analysis for investment in NEC in a more coherent and integrated way. The model will facilitate a more holistic treatment of critical human, organisational and social variables, which is necessary to effectively support balance of investment across lines of development or effective assessment of socio-technical systems.

A failure to successfully implement a requisite model of an agile HQ has significant implications for the way in which investments in NEC can be justified and managed. Current UK policy for military capability acquisition requires the use of cost-effectiveness assessment of investment options [MoD, 2004]. Without requisite modelling, such assessment is likely to be unreliable, and may be very misleading. Making investment decisions without reliable, holistic assessments of effect means that a more risk-taking and experimental approach to acquisition will be required.

Of course, it may be that such an experimental approach will be more effective in generating an evolution of C2 capability capable of achieving competitive advantage in Information Age conflict. However, the research, which underpins the conceptual model, suggests that the cultural and organisational changes needed for such a radical change in acquisition approach are unlikely to happen quickly and, in the meantime, it is worth striving for requisite modelling.

8. **References**

Alberts, D S, and Hayes, R E (2003) *Power to the Edge: Command and Control in the Information Age*, DoD/CCRP, Washington DC

Alberts, D S, et al (1999), *Network Centric Warfare: Developing and Leveraging Information Superiority*, DoD/CCRP, Washington DC

Alberts, D S, et al (2001), *Understanding Information Age Warfare*, DoD/CCRP, Washington DC

Avery, N J (2003), *A Critical Review of the Common Critical Success Factors Affecting Business Process Re-engineering in the Military Context*, MSc Dissertation, University of Southampton, Faculty of Social Sciences, School of Management

Boyd, John R (1992), A *Discourse on Winning and Losing*, (from <www.d-n-i.net/second_level/boyd_military.htm>, down-loaded May 2004)

Boyd, John R. (1996), *The Essence of Winning and Losing*, (from <hwww.belisariaus.com/modern_busines_strategy/boyd/essence/eowl_frameset.htm>, down-loaded May 2004).

Carter, R (1998), *Mapping the Mind*, Wiedenfeld & Nicholson

DND (1985a), *The Impact of Integration, Unification and Restructuring on the Functions and Structure of National Defence Headquarters*, DND S1/85, July 31 (from www.dnd.ca/site/reports/somalia/vol2/V2C17_e.asp, downloaded May 2004)

DND (1985b), *The Canadian Forces and the Department in War and Peace*, DND S3/85, November 15. (from www.dnd.ca/site/reports/somalia/vol2/V2C17_e.asp, down-loaded May 2004)

DND (1988), *The Report on the Functions and Organization of NDHQ in Emergencies and War*. (from www.dnd.ca/site/reports/somalia/vol2/V2C17_e.asp, down-loaded May 2004)

Dodd ,L, et al (2004), *Command decision-making with conflicting objectives: an exploration of some experimental data.* QinetiQ, Malvern, UK (in preparation).

Engleback, N, et al (2003), *Some Uses of Agent-Based Models in the New Zealand Defence Force*, in Horne, G & Johnson S, *Maneuver Warfare Science 2003*, United States Marine Corps Project Albert, Quantico VA.

Gott, M, et al (2003), *Adaptive HQ Modelling*, EDS Ltd, Hook, UK (unpublished report prepared for UK MoD)

Groth, L. (1999), *Future Organizational Design; The Scope for the IT-based Enterprise*, John Wiley & Sons, Chichester, West Sussex, UK

Holt, J (2003), *NEC Social and Organizational Factors*, Journal of Defence Science, Vol **8**, No 3, pp142-151

Klein, G A, et al (Eds) (1993), *Decision Making in Action: Models and Methods*, Ablex Publishing Corporation, Norwood, New Jersey

Klein, G. (1997), *The Recognition-Primed Decision (RPD) Model: Looking Back, Looking Forward*, in C. E. Zsambok & G. Klein (ed.), 1997, Mahwah, NJ: Lawrence Erlbaum Associates.

Kyriakidou O (2002) *Identity orientation and networking: Towards a conceptual framework for understanding of organizational change*. British Academy of Management, London, 9-11 September, quoted in Holt (2003)

Malish, P, et al (2003), *Contribution of the Human Element to Command Effectiveness – The Impact of Information on Command Effectiveness*, Defence Science and Technology Laboratory, Dstl/JA07514, June (awaiting publication)

Mathieson G. L (2001), *The impact of information on decision making*, Defence Science and Technology Laboratory, DSTL/JA02207, presented at 18th International Symposium on Military Operational Research (August)

Mathieson, G L (2003a), *Knots, lace and tartan - the need for scientific synthesis in OR*, Presented at 45th Conference of the Operations Research Society, Keele University (September)

Mathieson, G L (2003b), *Socio-Technical Systems - Practical OR in the face of the human variable*, presented at 20th International Symposium on Military Operational Research, held at Eynsham Hall, Oxford, September 2003a

Mathieson, G L, et al (2002), *The impact of organisational and cultural variables on HQ behaviour and performance*, presented at European Symposium On People In

Digitized Command And Control, held at Royal Military College of Science, Shriveham, UK, on 13th and 14th November 2002

Mintzberg, H (1979), *The Structuring of Organisations*, Englewood Cliffs, Prentice Hall

MoD (2001), Definition of NEC by Deputy Chief of the Defence Staff (Equipment Capability) dated November 2001, drawn from http://www.mod.uk/issues/nec on 14 May 2004.

MoD (2004), *The Smart Acquisition Handbook, Edition 5*, UK Ministry of Defence, London.

Moffat, J (2000), *Representing the Command and Control Process in Simulation Models of Combat*, Journal of the Operational Research Society **51** No 4 pp 431-439.

Moffat, J (2002), *Command and Control in the Information Age; Representing its Impact*, The Stationery Office, London, UK, 2002.

Moffat, J (2004), *Validation of the mission-oriented approach to representing command and control in simulation models of conflict*, Journal of the OR Society, Vol **55**, No 4, pp340-349

Noble D (2003), Private Communication from David Noble, EBR Inc, Washington

Sheldon, B & Upton S C (2003), *Analysis of Counterterrorism Using the Agent-based Model Socrates and Natural Algorithms*, in Horne, G & Johnson, S, *Maneuver Warfare Science 2003*, United States Marine Corps Project Albert, Quantico VA.

Sheppard, C, et al (2000), *Human Decision-Making in OA: Knowledge Requirements and Guideline Structure*, DERA/CDA/SEA/AIR/CR000070/1.0, Unpublished MoD report

9th International Command and Control Research and Technology Symposium

A Conceptual Model of Organisational and Social Factors in HQ

Graham Mathieson, Dstl Fellow

UK Defence Science and Technology Laboratory

Lorraine Dodd

QinetiQ

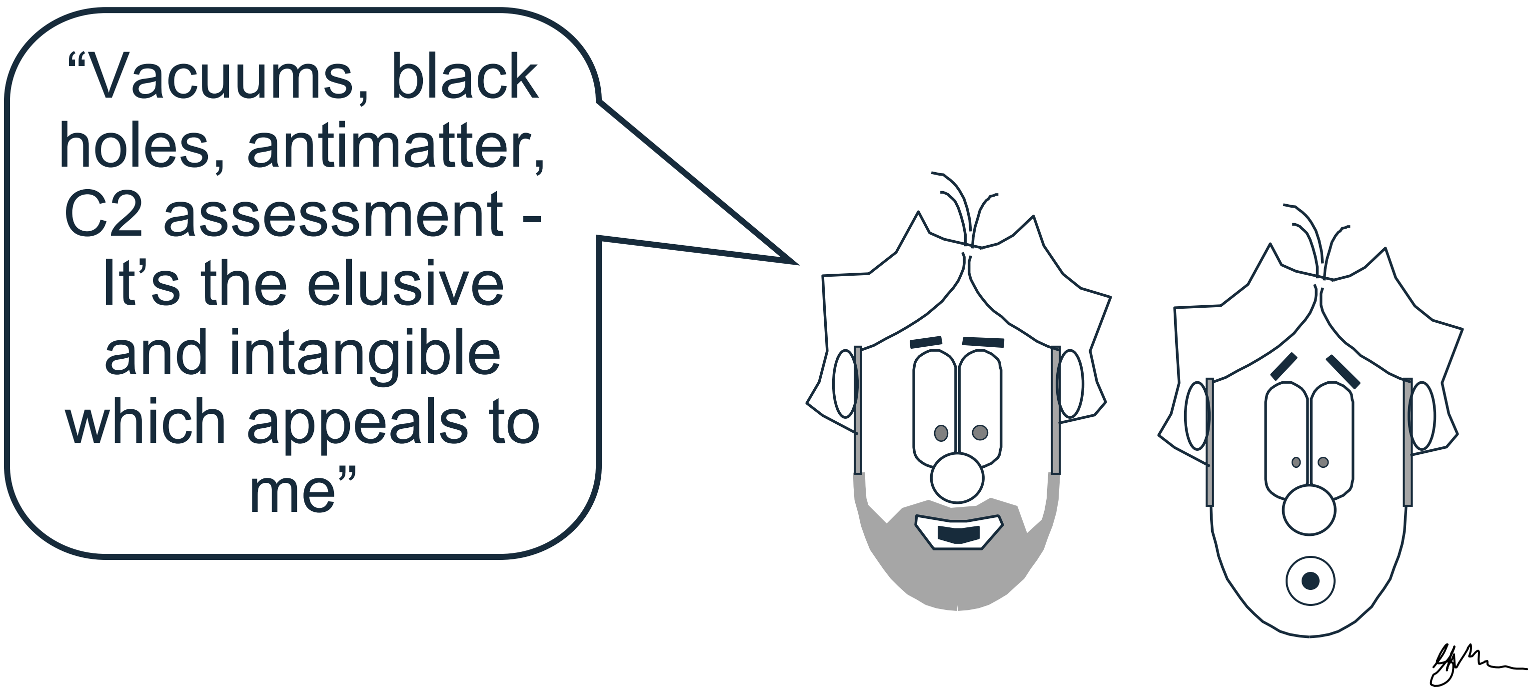
Structure of presentation

- Introduction
- Case study to illustrate issues
- Current knowledge
- Building the conceptual model
- Practical simulation methods
- Implications of success (or failure)

Introduction

- Information Age technologies enable collaboration at a distance, inviting military to adopt agile mission grouping.
- Assuming Commanders are not willing to allow total self-organisation, they will need agile HQ organisations as part of the wider development of Information Age C2.
- BUT, the HQ agility depends upon much more than shared understanding arising from information sharing
- Paper explores the implications of HQ agility from the standpoint of organisational and social science, and how the relevant issues might be handled by modelling

C2 problems tend to be complex and poorly defined



Case study to illustrate issues

- HQ reachback - Simple case with rich implications
- Three "options" for HQ reachback are considered:
  - No reachback - full HQ co-located in theatre;
  - In-theatre reachback - Core HQ forward; staff unit in rear;
  - Homeland reachback - Core HQ forward; staff unit in homeland.
- Potential benefits - smaller, more agile deployed element; staff in richly networked info environment
- Potential dis-benefits - loss of coherence and shared awareness, affecting motivation and performance

Current knowledge

- Much of the knowledge needed to understand agility in HQ's is already well established in the human sciences
- But HS disciplines not a coherent body of knowledge.
- Military OR needs to integrate disciplines like organisational theory, information theory and cognitive psychology - exploiting wide range of mature knowledge

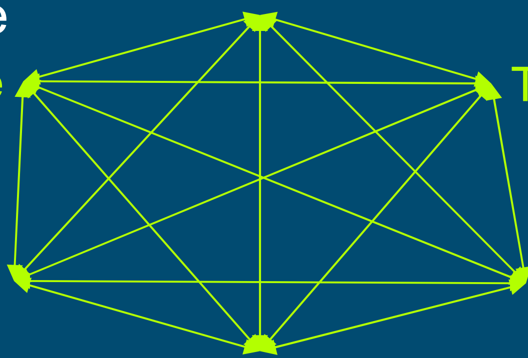
Things we know about socio-technical systems

Organisation size correlates with formality of interactions

Degraded comms system performance can lead to improved information service

People process information according to their culture, experience, expectation, emotional state

Technical system performance can critically depend upon human social phenomena



Humans naturally use very little of the information available to them

People create and use informal structures, which can be more influential than the formal ones

Even in safety-critical organisations, people do not consistently follow formal processes

It takes years to change an organisational culture without wholesale re-staffing

Structures emerge in organisations despite the intentions of the people involved

'Reachback' factors and impacts

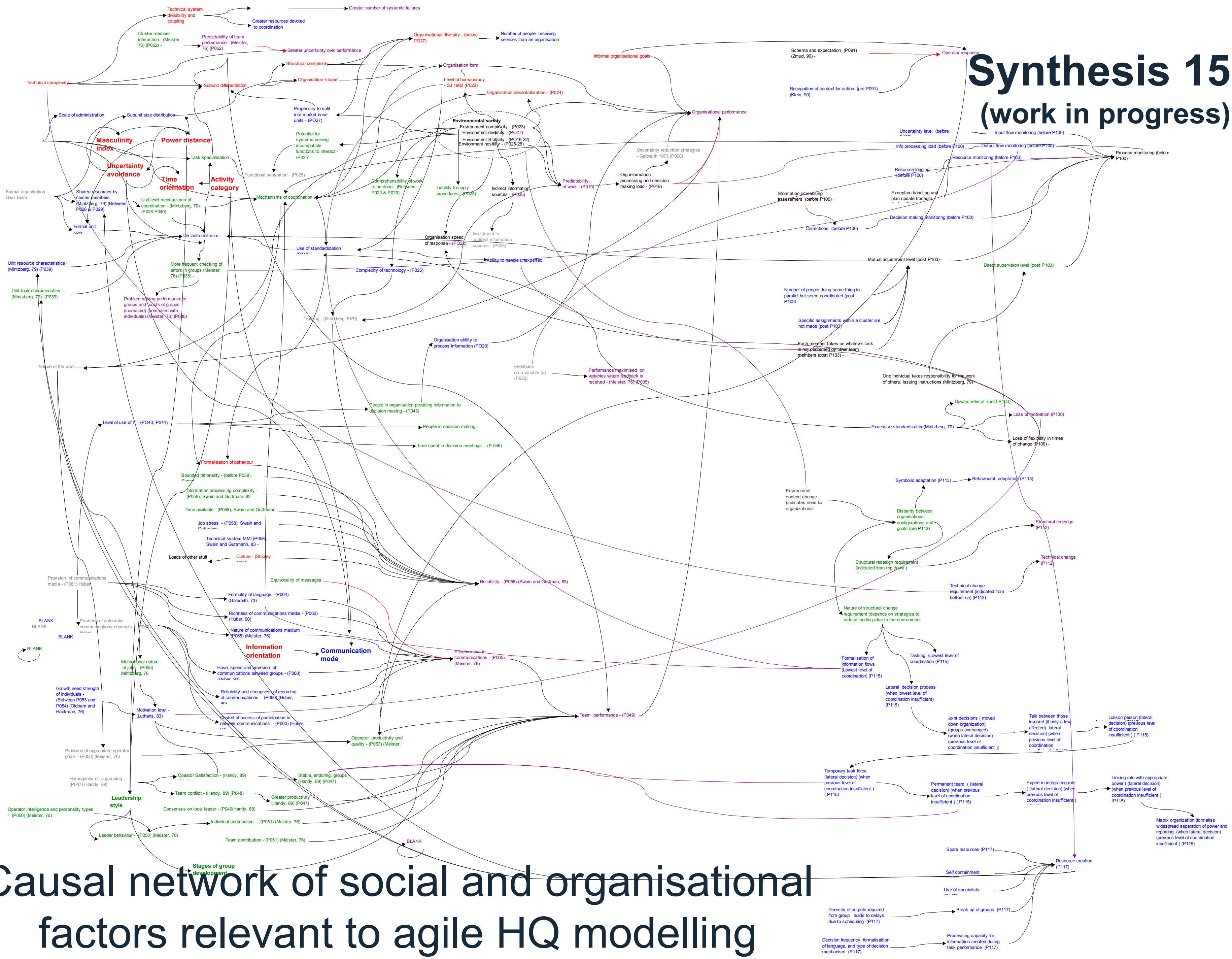
FACTOR		IMPACT AREA
Co-location	→	Teamworking
Use of computer-mediated communication	→	Understanding and trust within teams and mission groups
Leadership	→	Participation and morale
Use of information technology	→	Participation in decision-making
Formal roles and structures	→	Team behaviour

KNOWLEDGE AREAS: Social network theory, Organisational science, Cognitive psychology, Teamworking research, ...

Building the conceptual model

- UK is seeking to develop a demonstration of requisite modelling of an agile HQ, which includes social, cultural and organisational variables and effects.
- Synthesis of a wide range of scientific theory is needed, covering social (including organisational) and cognitive theories and constructs, to complement conventional informational and physically-based modelling.
- Proposed architecture balances breadth and depth, as well as being sensitive to danger of too much complexity.

Synthesis 15
(work in progress)



Causal network of social and organisational factors relevant to agile HQ modelling

Empirical evidence

- Anecdotal evidence from experienced military officers covering Op TELIC and earlier conflicts
- Human science analysis from Op TELIC Lessons Identified
- Consideration of specific case study examples covering reachback, network fires, and service provision

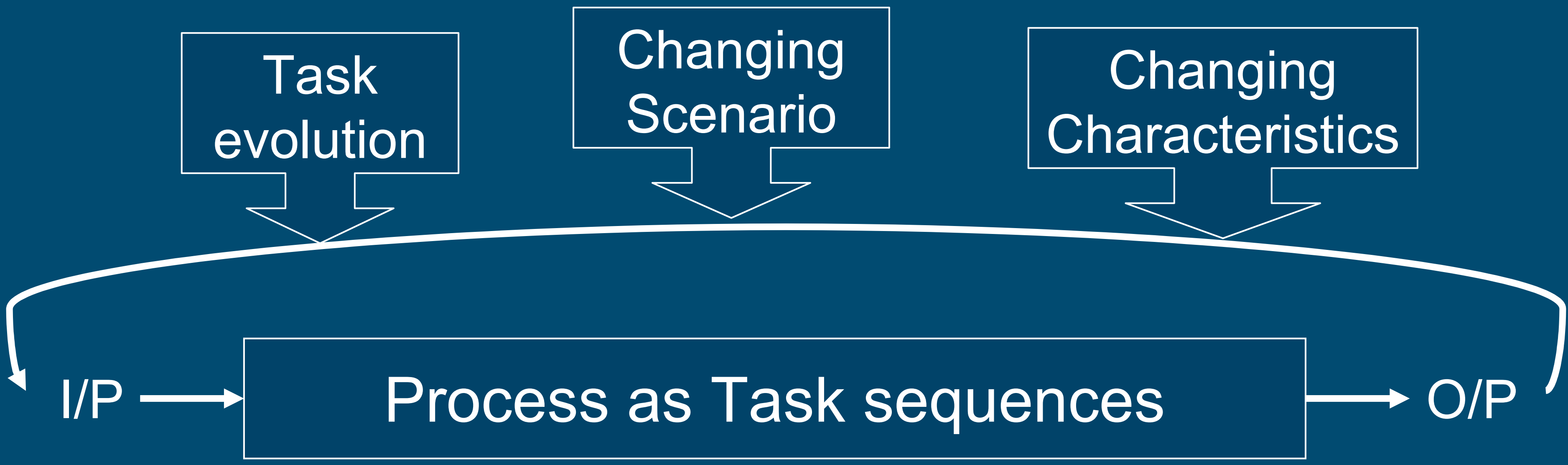
➔ It is concluded from the empirical evidence that it is important to include the full breadth of factors identified in the theoretical work, despite the resulting scale and complexity of the HQ conceptual model that this implies

➔ This is a challenge – 'best' advice from academe is to narrow the focus to a few nodes and links, which is unacceptable to OR

The emerging simulation design...

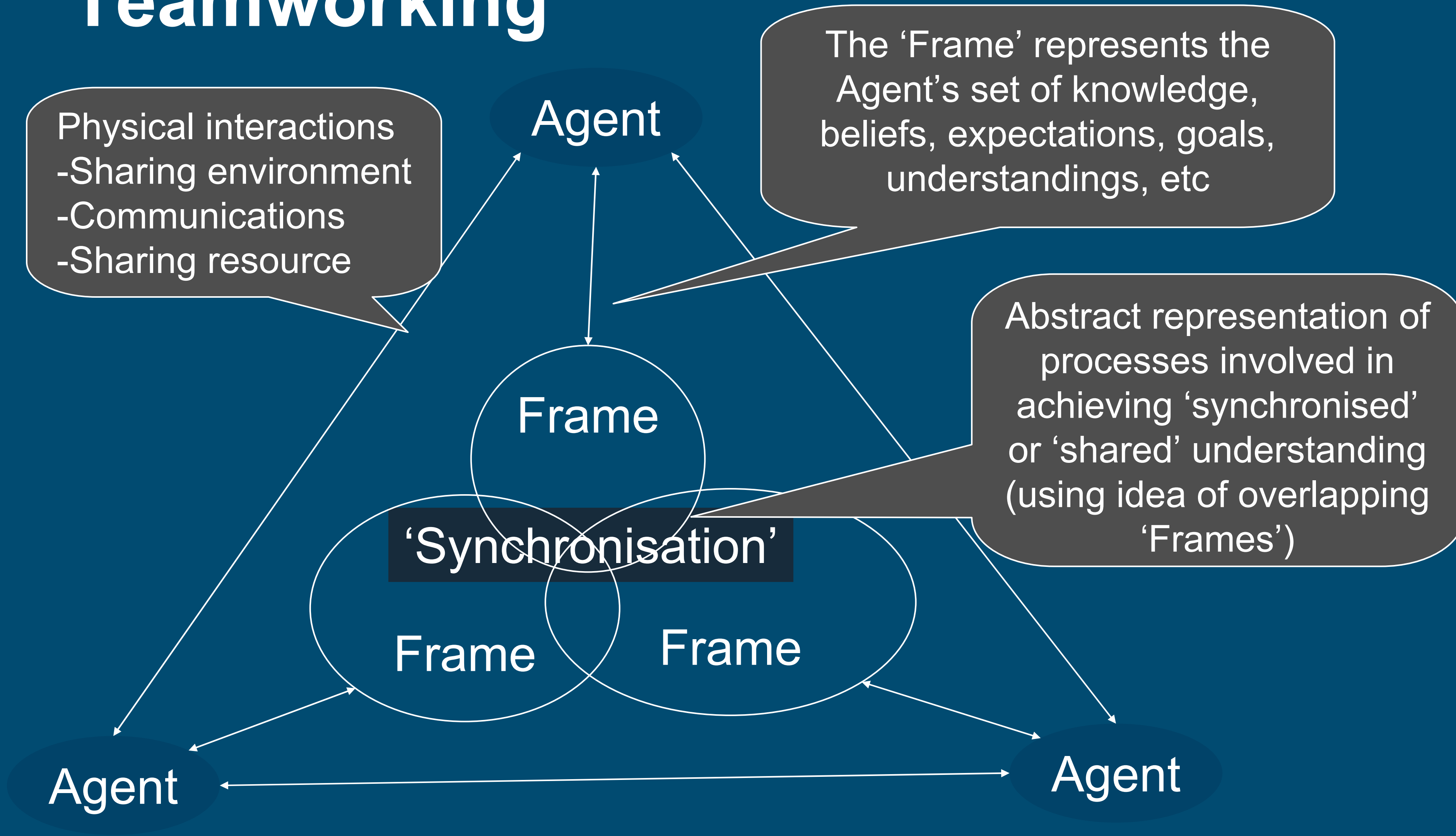
- To provide a vehicle for representing the breadth of variables identified in the theoretical work, any simulation will need to allow for variables associated with:
  - Taskwork (including process variability)
  - Interpersonal differences (physical, cognitive and social)
  - Teamwork
  - Organising (including formal and informal structures)
  - Socialising (probably needs to be fairly abstract representation)
- This could, of course, be covered in a federation of simulations, but they need to be integrated not separate

Taskwork (the ‘production’ process)



Dstl is part of the Ministry of Defence

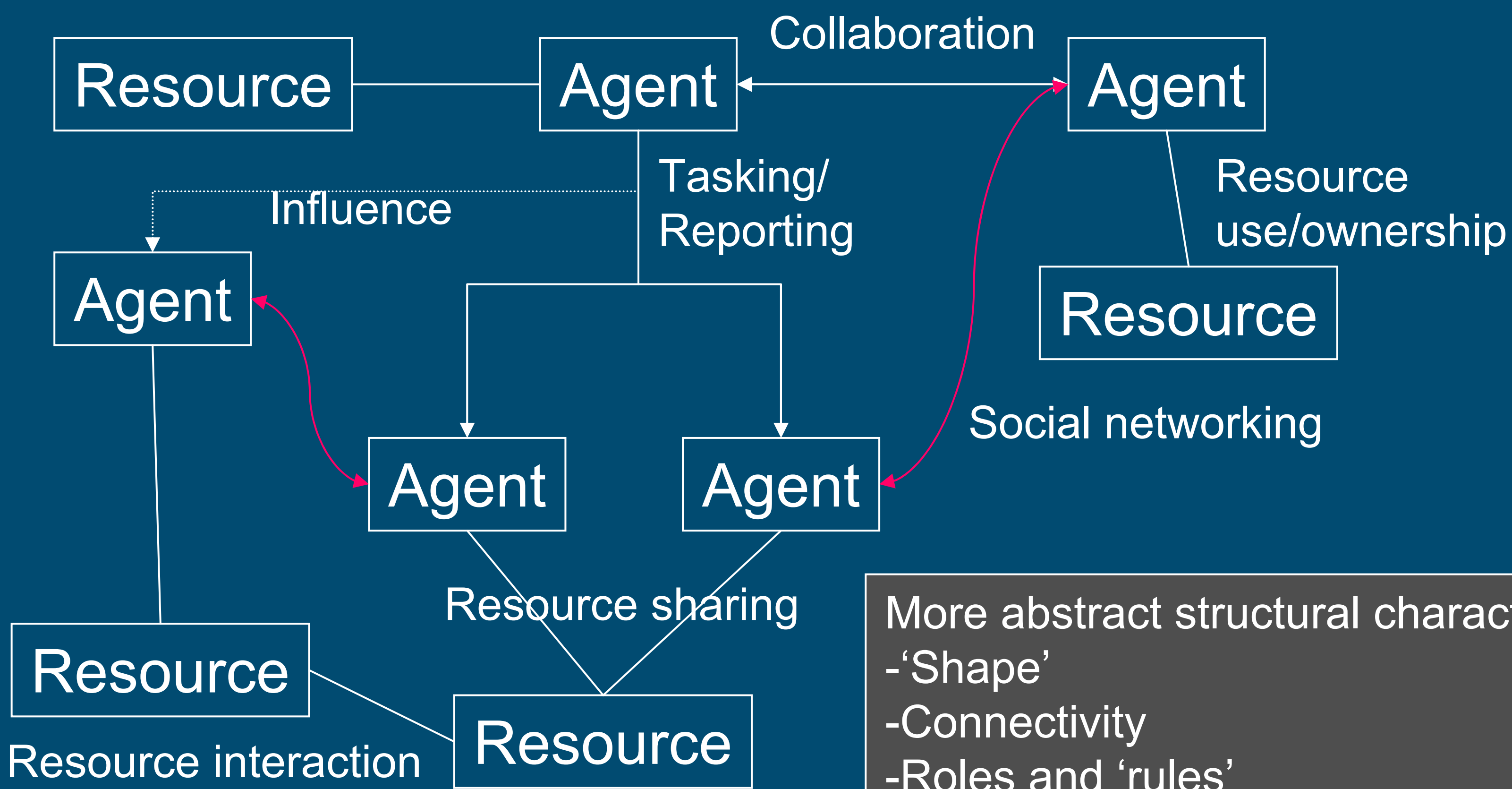
Teamworking



Team knowledge categories (Noble)

Knowledge Enabler	Definition
Goal understanding	Knowing what the customer wants
Understanding of roles, tasks, and schedule	Knowing who's supposed to do what and when, and with what information and resources.
Understanding of relationships and dependencies	Knowing how entities, events, and tasks impact the plan.
Understanding others	Knowing what other team members' backgrounds, capabilities, and preferences are.
Understanding of team "business rules	Having and knowing effective and agreed upon rules for team members interacting with each other.
Task skills	Knowing how to do one's assigned work.
Activity awareness	Knowing what others are doing now and current need for doing it.
Understanding of the external situation	Knowing status of people (including client), things, and events of the world outside of the team and projecting future changes.
Current task assessment	Keeping tasks on track, knowing how well own and other's tasks are progressing, and when to offer help.
Mutual understanding	Knowing what other team members understand now and knowing if they agree or disagree.
Plan assessment	Predicting whether the plan will still enable the team to achieve its goals.
Understanding of decision drivers	Judging and applying the criteria for selecting an action.

Structure view



More abstract structural characteristics
-'Shape'
-Connectivity
-Roles and 'rules'
-…

Emerging meta-model

HQ Process as Task transition network

Team knowledge determines whether team is forming, storming, norming, or performing

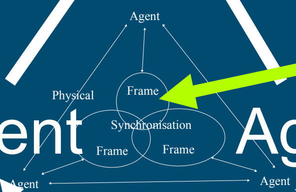
'Working together'

Teamwork/Taskwork 'balance' affects task performance/efficiency

Task 'team'

Gross Social processes influencing knowledge in agent and team Frames

Agent



Agent

Gross Structure processes influencing agent relationships and links to/between resources

'Being together'

Teamworking processes influencing knowledge in agent and team Frames

Practical simulation methods... (WIP)

HQ

Finite state transition model
Process modelling

ork

Team knowledge determines whether team is forming, storming, norming, or performing

'Working together'

Teamwork/Taskwork 'balance' affects task performance/efficiency

Task 'team'

Gross Social processes

Agent

Agent modelling
Knowledge state

Social network model
Mathematical modelling

'Being together'

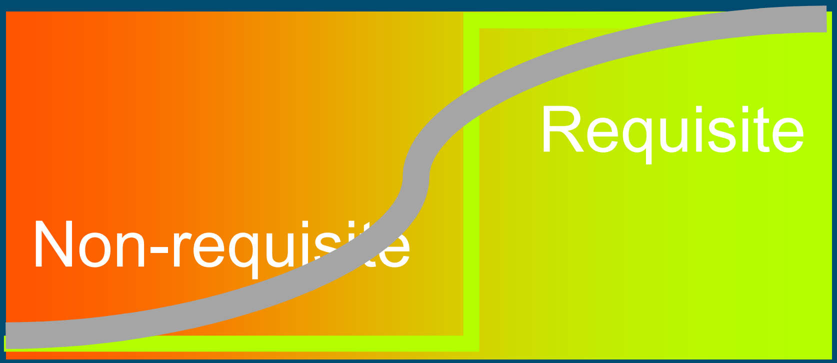
Teamworking processes influencing knowledge in agent and team Frames

and links to/between resources

Consequences of success (or failure)

- Success
  - Coherent, integrated analysis to support NEC/NCO decisions
  - Holistic treatment of critical human and organisational issues
  - Effective balance of investment across Lines of Development
- Failure
  - More unreliable cost-effectiveness assessments
  - Limited ability of OR to handle capability-based assessment
  - Need for a more risk-taking, experimental approach to capability acquisition and support to operations, with less use of models

Some definitions and declarations



- Models are abstract representations
  - descriptive/explanatory
  - conceptual/practical
- Requisite *(adj) made necessary by particular circumstances* (Concise Oxford)
- Requisite model is minimum that is fit for purpose
- Requisite model:
  - Contains all critical factors which may determine the study conclusions (e.g. factors significantly affecting option rank ordering)
  - Can be defined in relation to an isolatable sub-problem (i.e. one in which a sub-set of factors are not too dependent on others)
- Non-requisite, by implication, means not fit for purpose
  - Using non-requisite models carries risks. When is the risk too high?

Levels in Operational Analysis

- Level 1: Policy and Capability Studies
  - Campaign effectiveness, whole force, strategic planning and BoI
  - Resolving C2 effects across the whole network
- Level 2: System Studies
  - Mission effectiveness, multi-system/platform, capability planning and COEIA support
  - Resolving processes and components within C2 systems
- Level 3: Acquisition Support Studies
  - System effectiveness, usually single system/platform project
  - Resolving C2 technologies and system design options