NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

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RTO MEETING PROCEEDINGS **MP-HFM-143**

Human Behaviour Representation in Constructive Modelling

(Représentation du comportement humain dans des modélisations créatives)

Proceedings from the Specialists' Meeting held in Toronto, Ontario, Canada, 30-31 May 2007, in close coordination with Members of the HFM-128/RTG.

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The Research and Technology Organisation (RTO) of NATO

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

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

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

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Abbreviations

ACT-R	Atomic Components of Thought - Rational
BRIMS	Behavior Representation In Modeling and Simulation
CAN	Canada
DARPA	Defense Advanced Research Project Agency http://www.darpa.mil/
DDR&E	Director, Defense Research and Engineering
DoD	Department of Defense
GBR	United Kingdom of Great Britain
HBR	Human Behaviour Representation
HFM	Human Factors and Medicine
IMPRINT	Improved Performance Research Integration Tool http://www.arl.army.mil/ARL-Directorates/HRED/imb/imprint/Imprint7.htm
IPME	Integrated Performance Modelling Environment http://www.maad.com/index.pl/ipme
M&S	Modelling and Simulation
NATO	North Atlantic Treaty Organisation
NGO	Non-Government Organizations
NLD	Netherlands
OGD	Other Government Departments
R&D	Research and Development
RSM	Research Specialist Meeting
RTG	Research Technical Group
RTO	Research and Technology Organisation
SAF	Semi Automated Forces
SAS	System Analysis and Studies
SEAS	Synthetic Environment for Analysis and Simulations http://www.mgmt.purdue.edu/centers/perc/html/aboutperc/seaslabs/seaslabs.htm
SME	Subject Matter Expert
SOAR	State, Operator And Result http://sitemaker.umich.edu/soar/home
SWE	Sweden
TTCP	The Technical Cooperation Program
USA	United States of America

Programme Committee

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Mr. Joe Armstrong	CAE Professional Services Inc.	(CAN)

Panel

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Mr. Martin Castor	FOI, Swedish Defence Research Agency	(SWE)
Mr. Bill Fraser (TER)	Defence Research and Development Canada	(CAN)
Dr. Kevin Gluck	Air Force Research Laboratory	(USA)
Dr. Wouter Lotens (HFM/RTG-128 Chair)	TNO	(NLD)

Human Behaviour Representation in Constructive Modelling

(RTO-MP-HFM-143)

Executive Summary

NATO RTO has coordinated a number of studies into the modelling of personnel and platforms for use in military simulations (Dompke & Scheckeler, 1999; RTO, 2001) and interest in human modelling continues in a number of NATO RTO panels. RTO HFM RTG-128 on Human Behaviour Representation (HBR) in Constructive Simulation is in the process of providing guidance to operational analysts and engineers on human factors that can be included in operational models. Such models are used for various assessments – notably materiel, mission support and tactics – as well as training. The goal of HFM RTG-128 is to make recommendations to the HBR modelling community regarding the use of human factors in constructive models in a systematic way, paving the way for standardisation and re-use of modules describing specific human factors.

HFM-143/RSM "Human Behaviour Representation in Constructive Modelling" was initiated by RTG-128 as part of its activities to further the field of human modelling for NATO M&S. Thirty-three people with an interest in modelling human behaviour and performance from seven NATO member and Partners-for-Peace countries gathered at the Canadian Forces College in Toronto, Canada for a 2-day workshop (30-31 May 2007) to discuss, debate and exchange ideas on aspects of human modelling.

Each day started with a keynote presentation on HBR's role in simulation. The first keynote presentation, by Dr. Robert Foster, DDR&E, provided a government and NATO perspective, outlining the need to go beyond the requirements of traditional combat modelling to include the broader range of military activities including humanitarian aid and nation reconstruction, focusing to a greater extent on the human aspects of Effects Based Operations and non-kinetic warfare. The second keynote presentation, by Mr. Mike Greenley, CAE Inc. provided an industry perspective, noting the need for best-practice approaches to human modelling that evolve naturally rather than mandated constraints and that if industry perceives a viable market, such as the broader training of personnel, companies will participate in that evolution as partners. The following seven topic areas were then discussed in subsequent sessions:

1) What Human Factors Does an Operation Involve?
2) Human Task Representation in M&S.
3) Behaviour Generation: Variability and Choice.
4) The Concept of Moderators.
5) Militarily Relevant Mental Output Measures: Workload, Situation Awareness and Other Useful Concepts.
6) Complexity, Hierarchy, Modularity and Validity in HBR Architectures.
7) From Individual to Group Behaviour.

Each session comprised some introductory remarks by the session chair and brief presentations by researchers in the field to offer perspectives on the discussion topic. This was followed by a general discussion among the participants. The focus on plenary discussion with short presentations seemed to be well received and there was extensive participation in the discussions by all of the attendees.

There was general agreement with the points of view of the HFM-128 approach to documenting the human factors of HBR and that the community seems to be on the right track. Although progress in modelling human factors has been slow over the past decade, other forums have been reporting a number of theoretical and applied papers on human behaviour and performance modelling. While we are still a long way from turnkey models of operators, the consensus that various modelling approaches are useful gives confidence to move ahead in the field from a variety of perspectives.

Some of the key recommendations to NATO are:

1) Foster closer ties among NATO M&S stakeholders, including military, analysts (SAS) and human sciences (HFM) specialists to ensure that appropriate models are being used to represent the human element of military simulations, or if this is not practicable, then to recognize the limitations of the models being used.
2) Establish a mechanism to collect and disseminate operational or training data that are suitable for developing and validating models of individual and group behaviour and performance, particularly data that supports modelling for the "3-Block War" concept of operation.
3) Promote the development of an open architecture or interface specification that supports interaction of operator models from a variety of sources within military synthetic environments, particularly those environments that deal with the broader issues of Effects Based Operations and the activities characterized as a 3-Block War.
4) Promote the development and publication of formal models that support the analysis of Effects Based Operations, including the influences of culture, motivation and public opinion on individual and group behaviour.
5) Promote the use of HBR modelling approaches in military M&S for which the actions of individuals and teams play a critical role in the observed behaviours and outcomes.

Représentation du comportement humain dans des modélisations créatives

(RTO-MP-HFM-143)

Synthèse

La RTO de l'OTAN a coordonné un certain nombre d'études sur la modélisation du personnel et des moyens pour les simulations militaires (Dompke & Scheckeler, 1999 ; RTO, 2001) et l'intérêt concernant la modélisation des hommes se poursuit dans un certain nombre de panels RTO de l'OTAN. La RTO HFM RTG-128 sur la représentation du comportement humain (HBR) dans des modélisations créatives fournit des conseils aux analystes opérationnels et aux ingénieurs spécialisés sur les facteurs humains qui peuvent être insérés dans des modèles opérationnels. De tels modèles sont utilisés pour différentes évaluations – notamment pour les matériels, le soutien en mission et la tactique – ainsi que pour la formation. Le but du HFM RTG-128 est de faire des recommandations à la communauté de modélisation HBR concernant l'utilisation des facteurs humains dans des modèles constructifs d'une manière méthodique, en préparant le terrain par une standardisation et une réutilisation de modules décrivant des facteurs humains spécifiques.

Le HFM-143/RSM « Représentation du comportement humain dans des modélisations créatives » a été amorcé au sein du RTG-128 comme partie intégrante de ses activités en vue de faire progresser le domaine de la modélisation humaine pour le M&S de l'OTAN. Trente-trois personnes s'intéressant à la modélisation du comportement humain et aux performances humaines provenant de sept membres de l'OTAN et de pays Partenaires pour la Paix se sont donc réunis au Canadian Forces College à Toronto au Canada pour un atelier de 2 jours (30-31 mai 2007) pour discuter, débattre et échanger des idées sur les aspects de la modélisation humaine.

Chaque jour a débuté par une présentation sur le rôle de l'HBR dans la simulation. La première présentation faite par le Dr. Robert Foster, de DDR&E, a donné le point de vue des gouvernements et de l'OTAN, en soulignant le besoin d'aller au-delà des exigences concernant la modélisation de combat traditionnelle pour inclure le domaine plus large des activités militaires sur l'aide humanitaire et la reconstruction d'un pays, en se focalisant pour une bonne part sur les aspects humains des opérations basées sur les effets et des actions de combats non cinétiques. La seconde présentation faite par Mr. Mike Greenley, de CAE Inc., a donné le point de vue industriel, en indiquant le besoin pour une approche des bons usages de la modélisation humaine qui puisse se développer naturellement plutôt que par contrainte. Mais si l'industrie découvre un marché prometteur, comme la formation plus large du personnel, les sociétés participeront alors à cette évolution en tant que partenaires. Aussi, les sept domaines d'intérêt suivants ont été débattus dans les sessions suivantes :

1) Quels facteurs humains sont concernés dans une opération ?
2) Représentation de la tâche humaine en M&S.
3) Génération du comportement – variabilité et choix.
4) Le concept des modérateurs.
5) Mesures mentales militairement pertinentes obtenues – charge de travail, évaluation de la situation et autres concepts utiles.

6) Complexité, hiérarchie, modularité et validité dans les architectures HBR.
7) Du comportement individuel au comportement collectif.

Chaque session comprenait des remarques d'introduction par le président de session et des présentations brèves par des chercheurs dans le domaine pour ouvrir les perspectives sur les sujets à débattre. Cela était suivi d'un débat général parmi les participants. Le principe d'étude de point particulier en session plénière au travers de présentations courtes a, semble-t-il, été bien accepté et dans les débats, une participation étendue de tous les participants a été constatée.

Il y a eu un consensus général sur les points de vue de l'approche HFM-128 sur la façon de renseigner les facteurs humains dans le cadre de l'HBR et sur la bonne direction que la communauté semblait prendre. Bien que les progrès sur les facteurs humains aient été lents ces dix dernières années, d'autres forums ont rendu compte d'un certain nombre de communications théoriques et appliquées sur la modélisation du comportement humain et des performances humaines. Bien que nous soyons encore loin de modèles et d'opérateurs clés en main, le consensus sur l'utilité de différentes approches de modélisation donne l'assurance qu'il faut poursuivre dans le domaine à partir de différentes perspectives.

Quelques recommandations clés ont été données à l'OTAN :

1) Renforcer les liens entre les intervenants M&S de l'OTAN, en incluant les spécialistes militaires, les analystes (SAS) et les spécialistes des sciences humaines (HFM) pour s'assurer que les modèles appropriés ont été utilisés pour représenter l'élément humain dans les simulations militaires, ou si ce n'est pas possible, reconnaître alors les limitations des modèles utilisés.
2) Établir un mécanisme de récupération et de diffusion des données opérationnelles ou d'entraînement formation qui soient adaptés pour développer ou valider des modèles de comportement et de performance individuels et collectifs, en particulier des données qui soutiennent la modélisation pour le concept d'opération « 3-Block War ».
3) Promouvoir le développement d'une architecture ouverte ou d'une spécification d'interface qui soutienne l'interaction des modèles d'opérateur à partir de différentes sources dans les environnements synthétiques militaires en particulier ceux qui traitent des réponses plus larges des opérations en fonction des effets et des activités considérées comme « 3-Block War ».
4) Promouvoir le développement et la publication de modèles formels qui soutiennent l'analyse des opérations basées sur les effets, en incluant les influences culturelles, la motivation et l'opinion publique sur le comportement individuel et collectif.
5) Promouvoir l'utilisation des approches de modélisation HBR dans la M&S militaire pour laquelle les actions individuelles et collectives jouent un rôle critique dans les comportements observés et les résultats.

Chapter 1 – INTRODUCTION

NATO RTO has coordinated a number of studies into the modelling of personnel and platforms for use in military simulations (Dompke & Scheckeler, 1999; RTO, 2001) and interest in human modelling continues in a number of NATO RTO panels. Pew and Mavor's (1998) review of the field identified a number of shortfalls in the current state of the art, as have the above mentioned NATO and TTCP (The Technical Cooperation Program, Hawkins et al., 2003) reports. The RTO HFM-128/RTG on *Human Behaviour Representation in Constructive Simulation* is in the process of providing guidance for operational analysts, modellers and engineers on human factors that can be included in operational models and simulations that have personnel as a core element. Such models are used for various assessments – notably materiel, mission support and tactics – as well as training.

The goal of HFM-128/RTG is to make recommendations to the HBR modelling community regarding the use of human factors in constructive models in a systematic way, paving the way for standardisation and re-use of modules describing specific human factors. The modeller would then plug-and-play modules within standardised human factors architecture. HFM-128/RTG identified the requirement to hold a Specialists' Meeting in which the approach that the panel is following could be communicated to and challenged by specialists in the field, as well as to discuss a number of issues relevant to human modelling for military applications.

HFM-143/RSM "Human Behaviour Representation in Constructive Modelling" was initiated by HFM-128/RTG as part of its activities to further the field of human modelling for NATO M&S. A RTO Specialists' Meeting (RSM) technical team activity aims at promoting exchange of state-of-the-art knowledge among an audience of specialists with selected speakers on an important scientific or applied topic. The prime purpose of an RSM is to enhance the capability of the NATO R&D community to respond adequately to the military requirements of NATO.

Thirty-three people with an interest in modelling human behaviour and performance from seven NATO member and Partners-for-Peace countries gathered at the Canadian Forces College in Toronto, Canada for a 2-day workshop (30-31 May 2007) to discuss, debate and exchange ideas on aspects of human modelling. The list of attendees is included in the Appendices. The list of participants and the meeting agenda are provided in the Appendices 1 and 2 respectively.

The RSM was opened by the Co-chair Mr. Cain, stressing that the format of the meeting was intended to promote discussion rather than listening to formal presentations and that participation in the discussions by attendees was essential to the meeting's success. Two keynote speakers presented perspectives from NATO as well as from industry. These presentations served to set the stage for discussions, focussing on the HBR requirements and technologies that could be brought to bear on NATO M&S for the representation of personnel.

The following seven topic areas were discussed in separate sessions at the Specialists' Meeting and these proceedings summarize those discussions:

1) What Human Factors does an operation involve?
2) Human task representation in M&S.
3) Behaviour generation – variability and choice.

4) The concept of moderators.
5) Militarily relevant mental output measures – workload, situation awareness and other useful concepts.
6) Complexity, Hierarchy, Modularity, and Validity in HBR Architectures.
7) From individual to group behaviour.

Each session comprised some introductory remarks by session chairs and brief presentations by researchers in the field to offer perspectives on the discussion topic. This was followed by a general discussion among the participants. Presentations were kept brief to provide time to explore and debate ideas. This format seemed to be well received and prompted widespread participation by the attendees.

Summaries of the session discussions were written by the session chairs with input from the panel and various presenters; slides from the presentations are included in Appendix 1. The SM technical evaluator, Mr. Fraser, summarized the discussions at the end of each day, bringing out observations relevant to NATO. Mr. Fraser's technical evaluation of the meeting is included in Chapter 12.

Chapter 2 – OPENING ADDRESS

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This Specialists' Meeting is the result of discussions that were held over three years in the HFM-128 task group on HBR in constructive simulation. The similarity in the names is not coincidental. HFM-128 was tasked to find ways to implement human factors in operational modelling to address deficiencies in the more typical, mechanistic approach to modelling the activities of personnel or platforms controlled by personnel. The ideas emerging from that work will be documented in a report later this year. However, facing the moment that we have to formulate recommendations to NATO, HFM-128 considered that it would be prudent to consult the community on some of the issues being reviewed. Far more was addressed than we can discuss here, but we prepared seven items that may receive ample interest and are at the core of behaviour generation in models. The target audience for this Specialists' Meeting includes human factors specialists, developers of modelling systems and potential users. It was observed that there are few forums for these stakeholders to meet collectively and that having them together would be of benefit to all parties.

HFM-128 concluded that several deficiencies in human behaviour modelling still exist. Previous reports, such as from SAS-017 (RTO, 2001) and the two authoritative books by Pew and Mavor (1998) and Gluck and Pew (2005), identified a number of outstanding questions including:

- How can a balanced human factors input be given to operational modelling involving the relevant human factors with the appropriate accuracy?
- How can a range of likely behaviours be generated in a given situation and how is the selection made for the single behaviour that is activated?
- How do we obtain models that are fit for purpose, rather than selecting the nearest available model?
- What performance metrics can be applied in the military context of the simulated problem?
- Can we limit the effort of a study by reuse of sub-models and reduction of complexity?

HFM-128 developed a vision on these challenges based on scientific insights and operational developments that will be reported in its final report. Typically, in many applied models and architectures, scientific knowledge is neglected in the favour of convenient engineering techniques that are assumed to deliver valid results. In many instances this approach is no more than an engineering representation that fills a similar role to the human functions without consideration of the capabilities and limitations of the personnel they are attempting to characterize. The military modelling and analysis community need solid science-based representations of these human functions to have confidence in the validity of the resulting performance.

Studies need to be carefully framed to provide the context and military perspective required to produce useful results. Certainly, the advent of effects based operations has a profound impact on what behaviours are demonstrated, the performance that is realized and the metrics that should be applied to assess the outcomes. Classical measures such as time to completion and casualty counts may be subordinate to operational success or failure.

One way to reduce modelling complexity is through a moderator concept that allows analysts to separate human functions from states and traits yet still incorporate individual differences to affect performance on subtasks. These moderators affect task performance differentially, depending on the nature of the task and the moderator. The appropriateness of the moderator concept in human operator model is under debate but it has been successfully applied in some instances.

Cognition has a profound effect on behaviour and, in particular, decision making. Behaviour representation generally implies that a number of response options are available for given situations and that choices are not scripted, resulting in a different course of action. The control of the decision making and the cognitive process involved in decision making are key to generating plausible, validated behaviour and performance. Few if any of the in-service M&S tools consider aspects such as expertise and Naturalistic Decision Making, resorting instead to more mechanistic, Artificial Intelligence approaches.

This is a potentially powerful vision on a difficult subject and there are no ready answers. The discussions in this Specialists' Meeting have to reveal if the community agrees and NATO can be recommended to follow this route.

Chapter 3 – KEYNOTE ADDRESS: DAY 1 – REPRESENTATION OF HUMAN BEHAVIOUR IN CONSTRUCTIVE SIMULATION

Session Chair: Dr. Wouter Lotens
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THE NETHERLANDS

Presenter: Dr. Robert E. Foster
Director BioSystems
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USA

Dr. Foster set the framework for considering HBR "futures" by defining the "domains" for military applications of HBR in models and simulations. The key point was that developments in HBR to date have concentrated on tactical-conventional warfare and the emergence of world-wide "irregular warfare" and "small wars" drive the present and future need for a new scope of modelling. This emergent future was summarized in the domain space graph repeated in Figure 3-1. He pointed out that the new challenges to HBR in simulations are emerging from current military missions and can be expressed in the following shifts in the demand for research: from a conventional warfare tactical focus (the "B" space in the graph) to tactical – operational – strategic levels of military operations in irregular conflict environments (a HBR project depicted as "A" in the graph); from weapons-centered conventional missions to missions involving stability, support, reconstruction (SSTR) and governance support; from 24 hour tactical operations to longer term strategic initiatives lasting years. The new context is 'Non-kinetic warfare' in contrast to 'Military formation-based warfare' and the military focus is the spectrum of operations from irregular warfare to post event reconstruction. Non-kinetic warfare may require new approaches to modelling, whereas NATO militaries know how to develop and use "combat simulation" for analysis of formation based warfare. These existing real-time, integrated synthetic environments do not appear to be capable of supporting non-kinetic warfare modelling. There is a need for integrating available social science knowledge and models, possibly into new modeling environments such as "agent-based models". This is due to the possibility that extant military constructive simulations may not be able to be engineered to address social and cultural aspects of HBR as applied to non-kinetic military problems. While the US DoD has an emerging investment in research on human terrain and the socio-cultural understanding of conflict environments, much work in the M&S area needs to be undertaken to bring this science into the practice of formal military constructive simulations.

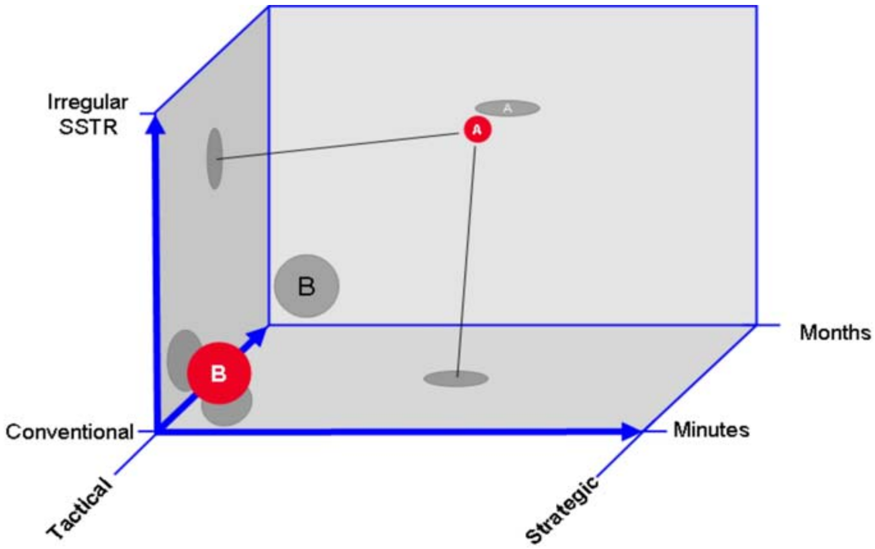

Figure 3-1: Conceptual Relationships Among the Factors Relevant to Traditional Military Manoeuvre Warfare Simulations and the Evolving Focus of Strategic Modelling for Non-Kinetic Warfare.

Among the other needs of NATO is authoring technology for developing human operator models. Operational experience has to flow into simulation environments more directly and the ideal way would be to let military Operational Analysts do the modelling, rather than the modeller. Later in this meeting it was doubted if this can be achieved anytime soon, because of the complexity and limitations of the human models, yet Pew and Mavor (1998) acknowledged the need for composable behaviours almost a decade ago.

A third need is validation, particularly of higher level simulations. Lack of data is an obstacle to validation of practical military simulations. The use of moderators is regarded as a primitive way to change performance. Confusion may arise about what a moderator is. Here, it was interpreted as a “dial” that influences the entity behaviour in a generic way, without distinction of goals and tasks, or as “white cell” entity handlers who manually control the behaviour of SAFs. Later in the meeting, a different definition of moderators was used that refers to formal, scientifically sound cognitive or physiological models that affect performance, for instance accurate thermal physiological, physical fatigue, or mental workload models. Game environments have the potential to be used as a test environment, notably “Real World” (DARPA) and “A Force More Powerful” (http://www.aforcemorepowerful.org/game/index.php). But, Dr. Foster pointed out, with the lack of evidence of validation or inclusion of scientifically based human moderating functions, do we have confidence in the predictions from these simulations? What should the research programs of the NATO nations address to move validation forward?

The audience wanted to know how scientists can collect the data required for model development and validation from the field. Although direct observation would be difficult, web based data collection using tools are in existence (e.g., LexisNexis; http://www.lexisnexis.com/) and could be assessed for feasibility. Another option is to leverage “blog”, “chat room” or other social network technology. The US Army is exploring this opportunity for data sharing by operating a ‘soldier-team-commander’ website to gather such data and lessons-learned from individuals in-theatre. Hypotheses might be tested on these raw observations to develop more general conclusions, as this is standard procedure in marketing research.

Dr. Foster admitted that modelling traditional/conventional combat activities is still prevalent. He was hopeful for progress in that there is expanding interest in the non-traditional modelling: in 2006 some 56 projects were sponsored on socio-cultural modelling that could be applied to analysis of Effects Based Operations in irregular warfare scenarios. And, there is an increasing understanding between engineers, computer scientists and the human science communities that interdisciplinary research is required to solve today's problems, such as improving the efficiency and effectiveness of the various, dispersed humans operating within Network Enabled Command and Control.

Chapter 4 – WHAT HUMAN FACTORS DOES THE OPERATION INVOLVE?

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4.1 INTRODUCTION

Pew and Mavor (1998) pointed out that Human Behaviour Representation (HBR) is a very challenging endeavour. We are trying to understand humans in complex contexts to the extent that we can write formal rules that describe human thinking, their behaviours, and the resulting performance.

A model, by definition, conceptual or computational, is a simplification of reality. Thus, a lot of abstractions and tradeoffs concerning level of representation have to be made in any modelling project. It is likely the case that HBR entails more abstractions and approximations than a model of a technical system, as human activity is so complex, and much has to be inferred about how the human "works".

As the choice of factors to include frames any modelling project, the organizing panel thought it would be fruitful to discuss whether or not the choice of which human factors to include in a specific model should be left up to the good judgement of the modeller. Further, would it be beneficial if we could gather some recommendations on how to move this modelling issue from art to more of a formal method. Thus, the topic for discussion was whether there are any formal approaches to decide what human factors to include in specific HBR projects.

One answer to the question of what human factors does an operation involve, and thus factors to include in a model, is that "it depends". The intention of the topical discussion was not to identify a long list of human factors that might affect an operation, but rather to see if good advice on how to formally approach the question of what human factors to include and scenarios to use could be gathered from the present HBR experts.

Related questions also raised at the introduction were:

- How do you link customer higher level questions to requirements for which human factors to include in the model? (e.g., How can the sustainability of a force be increased?)
- How to choose the appropriate fidelity level for representation?
- How to do trade-offs between level of detail and budget?

4.2 DISCUSSION

During the discussion, several modellers acknowledged that transforming the customer's higher level questions to design decisions of which human factors to include in a model was a challenging problem. To move this process from an art to more of a formal process, discipline by both analysts and customers will need to be high. Customers should clearly define what they want and not move their objectives as the study proceeds. Modellers should be very clear on why they include or exclude a certain human factor. A badly defined study will likely result in invalid, or worse misleading, results and customers should be educated about the need for and cost of validation. Validity is a big concern in all modelling projects. According to some modellers present, 60 – 70% of the study cost may be spent on data collection used to create and validate a model. Specialists may not agree with the customer on what he may get and the customer should take responsibility for the basic research that needs to be done in order to develop valid models in the direction they need. Data sets independent from the data that were used to shape the model are needed for evaluation of predictive validity.

The use of a human factors checklist and rationale for inclusion versus exclusion of each human factor in a modelling project was proposed. This checklist could take the form of a guided interview that could also be a basis for classification of models. Such a guided interview could form the basis for discussion with the customers on what to include and what to leave out.

The question was raised whether the granularity in model studies is sufficient to test hypotheses. One suggestion was to analyze the relationship in the literature between human factors and state variables to deduce specific hypotheses, rather than doing statistical analyses. Statistics do not reveal causes, just co-occurrence.

When a model permits the manipulation of many variables, it is good practice to initially manipulate only one at a time to gain understanding of how this factor affects the model. Even though this might be part of basic good practice for any scientific study, at least one anecdote from the discussion suggests that some end users of modelling software (rather than modelling specialists) manipulate many or all variables at once, stressing the models beyond their original design scope and causing them to fail in unexpected ways during execution. Development and use of models still requires in-depth knowledge of the application domain, the model, the modelling environment, the simulation settings, and the objectives of the study to have a reasonable expectation that the results obtained are meaningful.

The decision of which human factors to include in a model should be taken in light of where the model will be used (e.g., an acquisition project). If the factor, due to what stage the project is in or other reasons, cannot be affected, the rationale for inclusion of this factor decreases, i.e., the "So what?" question. For example, if recruitment to the army will never be based on personality type, the inclusion of this factor in a model of personnel selection and placement procedures might be less important than some other factor that can be affected.

The short-term versus the long-term requirements of a model can provide input to which human factors to include as well as the appropriate level of representation and abstraction. A simple model can be cheaper initially, but can become more expensive in the end if it has to be remodelled rather than simply elaborated in the future projects. We must also realize that we are a long way from turnkey applications of HBR and that there is no cookbook for abstraction; abstraction and modelling is an art and a skill guided by knowledge.

4.3 SESSION RECOMMENDATIONS

1) The use of a NATO developed checklist of existing human factors and presentation of why each factors was included or excluded in a specific model should be part of good practice.

2) It is still necessary to emphasize the need for "hooks" in the simulation of the physical environment where the behaviour models can get information form. It is also necessary to link HBRs to a context so that the effects of model behaviour are seen more clearly.

3) NATO should develop an ongoing capability to collect and disseminate data to support modelling of non-kinetic warfare, asymmetric situations and the long terms problems faced by commanders on a strategic level, as addressed in Bob Foster's keynote presentation. Much of this data will involve human factors from a number of domains.

4.4 PRESENTATION

In order to provide one example of a modelling project where the discussion topic could be exemplified Andy Belyavin presented an overview of a project concerning the prediction of aircraft collisions in the UK Low Flight System. The example showed that considerable insight into problems can be achieved by including relatively few human factors, but that these factors have to be chosen judiciously to be successful.

Also discussed was the need for a modular modelling environment that allows the analyst to expand the model as additional questions are asked that were not part of the original project problem scope or design specification.

Chapter 5 – HUMAN TASK REPRESENTATION IN M&S

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5.1 BACKGROUND

The representation of human behaviour in M&S begins with the question of how to best represent the tasks being performed, that is, the activities being carried out that constitute behaviour. How should the steps and sub-steps of activity, the overt and the 'black box' aspects of a task, the motor and the cognitive decision making elements of a task be translated into M&S software? How should you begin? Given that most of the models of human behaviour in use today have roots in the human factors community, task representation typically begins with some form of task analysis. Subject matter experts (SMEs) are used to develop a structured 'list' that captures the tasks of interest. Task analysis methods vary with respect to the details depending on whether it is a mission-function-task decomposition, a cognitive task analysis, a goal-directed task analysis, a work-centred approach, etc., but the general result the same. Generally, tasks are modelled as a sequential or networked series of steps of behaviour on the order of seconds or minutes. For many purposes, when the tasks to be represented are orderly and operators follow procedures, this may suffice; however, there are several factors that may influence human task representation in M&S and humans often deviate from procedures, often with good reason.

5.2 DISCUSSION

5.2.1 Expertise and Learning

Two related factors that influence how a task is to be represented are expertise and learning. There is new evidence emerging from research using brain imaging such as functional Magnetic Resonance Imaging (fMRI) that shows that experts have an overall lower brain activation during performance of the tasks of interest than do non-experts, suggesting that individual steps have become one larger step or 'chunk'. This result is consistent with the finding reported in the naturalistic decision making literature (see Klein for additional insight: Zsambok & Klein, 1997) that experts very often cannot express the detailed steps they performed as a part of a larger task. This is both problematic and interesting for HBR. On the one hand, SMEs are a main source of information about the tasks to be performed, but if they cannot verbalize what the steps or procedures are, then the task analysis is incomplete in some sense. On the other hand, the difference between novices and experts (going from many task steps to a single, more efficient task step) may be important to represent directly. Discussion of this topic at the RSM covered the role of implicit judgement, limited deliberation (not 'over-thinking' a decision), recognition-primed decision making, pattern-matching in expert decision making and the associated implications for task representation in M&S. Most of the discussion referenced military decision making but pertinent examples from economic decision making (e.g., buying a car) were given as well.

In addition to experts thinking of the task in a unitary fashion, as a 'chunk', rather than as a series of sub-steps, there is evidence that, since they are actually using fewer cognitive resources, they are better able to 'multi-task' and attend to other aspects of the environment, which, in turn makes them better able to detect anomalies and to do error correction, all of which would need to be accounted for in a model of expert performance. The matter of pattern-matching raised the question of whether this simplifies the modelling process or creates new difficulties. A model that includes pattern-matching, ideally, would include matching based not only on surface features, but also based on temporal, relational and procedural features characteristic of analogical reasoning theories (Thagard, 2005). What about the case when a novel pattern of events unfolds that does not have a match? It was suggested that a two-system or hybrid model that includes both symbolic and subsymbolic processes (such as ACT-R: Anderson & Lebiere, 1998) may be useful for this level of modelling.

Modelling expert performance, however, begs the question of how the expertise was gained in the first place. So, the question is, could a model of expert behaviour be created by having the model learn in the same fashion as a person? This could be accomplished by repeated exposures to the tasks to be learned, with a representation being built up and modified over time. Some modelling approaches offer the capability to learn, although they are not in widespread use as of yet.

5.2.2 Context

Another factor that will influence task representation is context and, specifically, the degree to which context is 'hard-coded' versus one more element the HBR must draw from the M&S environment. On the surface, humans implicitly understand the nature of a task without it being described in detail, without it being broken down into sub-tasks and small steps. The challenge arises when the task is to be represented computationally. At home, the task 'wash the dishes' evokes the entire context (the dishes are dirty, that hot water, a basin, soap, and so on) is available and the motions follow as a matter of routine. However, language is ambiguous; different cultures will have different interpretations of the same general task language. The humorous military example was given of the task 'secure the building', which is interpreted differently by the different services.

- The Army would surround the building with defensive fortifications, tanks and concertina wire.
- The Marine Corps would assault the building, using overlapping fields of fire from all appropriate points on the perimeter.
- The Navy would turn out the lights and lock the doors.
- The Air Force would take out a three-year lease with an option to buy the building.

The RSM discussion covered two points: One, that representing context – including the immediately prior history, the training, social, and cultural background being instantiated, the ability of humans to sort through the ambiguities of language – are challenges for high fidelity task representation; Two, that ensuring a common understanding of the nature of the task representation between the SMEs, the customer, the modeller, and others in the modelling community is a problem of semantics and of perspectives that must be dealt with directly at the beginning of a modelling effort and revisited throughout the project to ensure a good outcome. For example, the definition of a 'rule' differs depending on the modelling approach being used. A suggestion from the RSM attendees for distinguishing between rules and pattern matching (which may be implemented as a logical rule in the software) was that perhaps rules can be expressed explicitly as opposed implicit pattern-matching that might be expressed sub-symbolically or via a neural network.

5.2.3 Goal-Directed Representations

A third factor is the degree to which tasks should be represented as goal-directed versus as a set of steps that are executed essentially in order once the series is initiated. A goal-directed representation better enables an HBR to switch priorities based on new or additional information available in the M&S. Goal directed representations may also better characterize naturally occurring errors such as errors of commission and to have more flexible error recovery, to perform multi-tasking requirements in a realistic fashion, etc. A related aspect of a goal-directed task representation (such as Hierarchical Task Analysis, HTA: Annett, 2003; Annett & Duncan, 1967) is whether the representation is of the precise methods to be accomplished (e.g., these six steps in this exact order) or of the end result (e.g., 'take the hill'). The goal-directed approach allows for variability in methods employed to achieve the end, but also requires a more complex model. It was asserted by an RSM attendee that goal-directed modelling 'does not come for free', as has been found with the BDI (beliefs, desires, intentions) approach to agent modelling.

Additionally, the degree to which the methods are modelled in detail versus only as the end product can be thought of in a nested fashion: the details of the process at one level of granularity constitute the window into the black box of the higher level, and, in turn, the details at that level could be exploded into greater detail at the next level. For example, the 'task' of sending a message could be modelled as a series of steps (turn on system, type, check, press send), or the task could be modelled as just that, a single action that takes a certain amount of time in the aggregate. Or, if it fits the purpose of the model, the task of sending a message could be modelled at the level of milliseconds and involve the processes of perception, recall from memory, essentially simultaneous motor actions, errors, error correction, etc.

5.2.4 Emotion

A final factor identified by the RSM attendees as influencing the nature of human task representation in M&S is emotion. The literature on the role of emotion in decision making is of increasing interest to the military modelling community with new emphasis on operations other than war and effects based operations. Positive versus negative emotions seem to play an important role in memory and decision making. To some degree, emotions can be considered a stressor or a performance moderator with task and context-specific dependencies indicating a positive versus a negative outcome.

5.3 CONCLUSIONS

The choice of task representation is influenced by numerous factors in the application area – expertise and learning, context, goal-directed representation, and emotion. There are other factors as well, many of which are linked to the other discussion topics in the RSM: which human factors to represent, variability, moderators, and modelling at the individual versus team or group level. It can be concluded that the outlook for task representation is good for HBR, with a solid base having been established with a task network modelling approach. However, in order to represent the more complex aspects of human behaviour that underlie complex decision making in the full range of military operations, the additional factors discussed at this RSM must be incorporated into the HBRs being used in common practice.

Chapter 6 – BEHAVIOUR GENERATION: VARIABILITY AND CHOICE

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6.1 BACKGROUND

Human variability, or human variation, is often used to refer to the range of possible values for any measurable human characteristic (mental or physical). Examples such as the ability to learn, differences in physical strength or endurance, all may serve as moderators to behaviour in some contexts. Expanding the definition of human variability to include the range of possible behavioural outcomes, or behavioural variability, which may be observed for any given human operating within an operational context (e.g., the representation of fight versus flight behaviour), provides a significant challenge for the modelling community. In the context of improving realism and increasing the predictive abilities of Human Behaviour Models (HBMs), developing accurate and representational models of behavioural variability remains a desirable yet elusive goal.

Indeed, the NATO M&S Master Plan (NATO, 1998) notes that current computational models and simulations of operator and entity behaviour do not adequately represent human performance, neither at the individual nor the small group level. Current Computer Generated Forces (CGFs) rely largely on rule-based behaviours that are tied closely to doctrine, and while doctrine is often modelled, it is seldom observed in a pure form in practice. Predictability (i.e., lack of variability), based on textbook doctrine, may be desired for preliminary instruction or training basic skill development, but it is inadequate for advanced training in decision making, situation assessment, experimentation with tactics, or the evaluation of novel systems and procedures.

This session will attempt to clarify a number of questions that remain unanswered with respect to modelling behavioural variability. Are there adequate analysis techniques that can be leveraged to generate an adequate understanding of the factors underlying behavioural variability? How do we integrate the generation of behavioural alternatives and provide a mechanism from which these alternatives are executed? How does one characterize appropriate versus inappropriate behaviour, and how does behaviour relate to the concept of error?

6.2 SPEAKER PRESENTATIONS

Mrs. Carol Cooper-Chapman, Defence Science and Technology Laboratory

Dr. Chapman and colleagues at DSTL are establishing a modelling framework based on the works of Endsley (Endsley, 1993, 1995, 1998), Klein & Rasmussen that will support the inclusion of behavioural variability in their paradigm.

Dr. Emiel Ubink, TNO

Dr. Ubink presented an HBR modelling paradigm using a pandemonium model of behaviour that TNO is using to explore the performance and behavioural characteristics of soldiers in operational contexts. The representation of behaviour is produced through the combination of the effects of stressors (fatigue, core body temperature, workload, etc.) with task-specific knowledge. Changes in the states of stressors are used to modify task selection thereby producing behavioural variability in the HBR. In their current application, the TNO tool supports the representation of multiple entities, and is somewhat reminiscent of a SAF system in that the level of representation appears to be more tailored towards modelling the behaviour of an overall force structure (platoon, company, etc.) than individual entities.

The pandemonium model employs daemons that shriek for attention (a metaphorical prioritisation scheme) although it isn't necessarily a winner take all rule as it considers the resources that are available to accomplish the goal of the shrieking daemon. The use of a resource by a behaviour leads to a reduced capacity, as do stress and strain, directly resulting in variable behaviour.

6.3 DISCUSSION

6.3.1 Levels of Complexity

Determining the extent that a model must include variability, and therefore complexity, is an important aspect of building better HBRs. The decision to include elements of behavioural variability should be considered carefully, and must be supported by the requirement to represent different aspects of behaviour to support a specific research objective. Caution must be taken not to fall into the trap of providing significant levels of variability without just-cause. Indeed, examples were provided by the audience demonstrating that in extreme cases, overly complex models will often fail to perform at all, or exhibit behaviours that are so unpredictable as to render the model highly unstable. It was also noted that the ability to switch variability on and off may be an important feature both during development and during use of the model.

6.3.2 Types of Variability

Sources of behavioural variability typically arise through two domains: within individuals or between individuals. The ability to provide an accurate representation of the possible actions that a specific individual could use to respond to a situation is important for individual behavioural variability. This implies that modellers must be aware of the breadth of behavioural outcomes, and therefore the task-specific knowledge that must be represented within a model. Data driven concepts from theorists such as Klein and his Recognition Primed Decision Making (RPDM) model reflects the notion that variability is situated in the environment, and that this source of variability is what simple models may process to produce more complex and variable behaviour.

In its simplest form, the representation of between-individual variability reflects both the differences in task-specific knowledge and drivers of task-selection across individuals. In the military domain, obtaining the relevant task-specific knowledge from Subject Matter Experts (SMEs) is critical to achieving realistic behavioural variability. However, extending between-individual variability into the representation of Cultural Variability is challenging due to the lack of available SMEs in most applications. In either case, the use of SME input to establish branches for alternate behaviours is a costly, labour-intensive process, and the SME may not give represented answers that lead to plausible behaviours.

6.4 CONCLUSIONS

Overall it was agreed that variability is best represented through between-subject differences, or through within-subject variability that reflects both differences in the knowledge, states and traits of an individual. Current difficulties arise through the lengthy and time-consuming requirements to identify relevant knowledge for given situations, and establishing realistic links between state, trait and environmental characteristics that give rise to the selection of alternative tasks. Future work should focus on building better learning models that can produce new knowledge based on past experience, and incorporate this knowledge into the selection of behaviours. Ultimately the representation of variability must remain plausible; otherwise the inclusion of variability within models will become random and unexplainable.

Chapter 7 – KEYNOTE ADDRESS: DAY 2 – A ROADMAP FOR HUMAN BEHAVIOUR MODELLING

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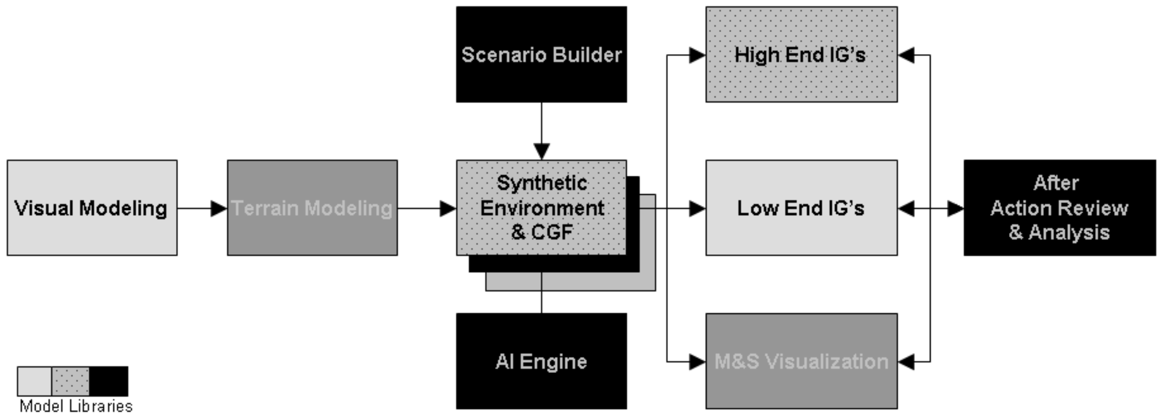
Mike Greenley from CAE, Inc. presented a vision for the future of human behaviour modelling from an industry perspective. CAE is a global leader in the design of civilian and military training systems for air, land and sea applications, having supplied the defence forces of more than 50 nations with military training systems and services. CAE offers a range of simulation equipment and M&S software that span the military domain into civil emergency management applications, where the incorporation of behaviour models for entities such as terrorists and civil actors is becoming increasingly important. This experience provides a broad base of M&S expertise that can be applied to predicting the needs of HBR in future military M&S.

Mike noted that accurate representations of human behaviour are becoming increasingly important for the conduct of military and civilian M&S activities across the domains of training, experimentation, and acquisition support. However, the current market space for Human Behaviour Modelling (HBM) is relatively fragmented, un-standardized, and does not support a coherent approach to the development of cost-effective HBM applications that can adequately address client requirements. Close collaboration between customer stakeholders, academic research institutes, and industrial partners is key to the advancement of state-of-the-art HBMs and to support the development of standardized methodologies for the application of HBM techniques. Successful collaboration will be contingent on the clear identification of the roles and responsibilities of industry, academic, and government stakeholders in the joint evolution of HBM technologies and practices.

Mike also identified that a requirement for re-usable software is driven by the need within the client domain to reduce the necessity of re-engineering or re-creating components developed for one application into another. In the concept of an overall simulation architecture, an important component relevant to the HBR community is to provide modular and Advanced Intelligence Solutions (AIS) characterized by the figure below, while maintaining a balance between optimization solutions such as those espoused by the AI and Robotics communities, and the accurate representation of human behaviour.



Mike also provided some insights into future growth areas for HBR, including:

1) Significant interest from the training community in providing higher-fidelity models of entity behaviours, intelligent tutors, and team-mates. In addition, exploitation of the current training market is estimated at approximately 10 percent. Expanding this domain into simulation support for corporate leadership is potentially even larger.

2) Though the desire for standardized tools and methodologies for developing HBR applications is substantial, standardization will only succeed where there is a clearly identified need that is driven by the client community and a specific application. Orchestrated standardization is extremely difficult, and history has demonstrated that this approach is not likely to succeed.

3) A major challenge for HBR applications is the difficulty in moving HBR capabilities from one simulation domain to another. However, software languages are beginning to emerge for the development of translation languages that will support the migration of modular HBR applications from one environment to another.

Chapter 8 – MILITARILY RELEVANT MENTAL OUTPUT MEASURES: WORKLOAD, SITUATION AWARENESS AND OTHER USEFUL CONCEPTS

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8.1 BACKGROUND

The interaction between cognition and context in the military environment is frequently summarised in terms of high-level constructs such as Cognitive Workload or Situational Awareness. By using these constructs it is possible to identify in qualitative terms the kind of corrective action that will improve crew performance and, in some cases, provide metrics that can be used to estimate the size of the improvement. The question arises as to whether it is useful to construct models of these high level constructs that can be used in conjunction with Human Behaviour Representations to support the same analysis.

There are two lines of argument that will serve as the basis for discussion. The first argument is that both workload and situational awareness have been developed as constructs because of the *lack* of understanding of basic cognitive processes and if there is an adequate model of cognition there is no need to consider these high level abstractions in the analysis of context. If this argument is accepted, the development of good quality cognitive models will eliminate the need to consider the high-level constructs and they will gradually fall into disuse.

The second argument is that these constructs provide a useful description of human performance in complex situations, providing a means to test and validate our models. If they fail to describe what we understand about workload, situational awareness and similar measures they are clearly not useful models. At the heart of this discussion is what do these output metrics measure and what is their utility in terms of modelling human behaviour.

8.2 DISCUSSION

8.2.1 Pleasing the Customer

It was clear from the discussion that some customers request output from models that is on the level of constructs such as workload or SA. It was argued, therefore, that human modellers should provide these measures, otherwise someone else (likely without an appropriate human-sciences knowledge base) will do it, but will probably do it badly. Another point in favour of using these constructs is that subjects do report, or at least are able to report, experiencing things such as "workload". Our models should therefore also generate such subjective responses.

It was argued that we could bypass the problems with these constructs if we would not use them as modelling concepts, but would generate these fuzzy constructs from the information present in the model. The main value in these concepts is as summary output measures that communicate aspects of performance to stakeholders.

8.2.2 Terminology

Most of those participating in the discussion agreed that many people outside of the Human Factors community use loose definitions of SA, viewing it as a concept solely related to sensors, data and displays rather than cognitive processes or knowledge state associated with understanding of the state of the immediate environment, as defined by Endsley and others. HBR modellers might therefore be better off using the term "sense making" instead, to distinguish SA from the technologies that support the acquisition of SA.

8.2.3 Containers

The general opinion was that these constructs are actually containers representing more complex and distributed phenomena. Workload could probably better be described as a collection of bottlenecks, instead of one big bottleneck. A similar argument holds for SA, since SA is probably a distributed (and somewhat fuzzy) collection of facts and interpretations of these facts that can not be localized or concretized.

It was argued that devoting energy to modelling these constructs to high fidelity is a poor investment of resources, since they are at best of limited use as modelling constructs. These constructs are therefore not to be used as a starting point of the modelling process but will evolve when "correctly" modelling performance (workload) and behaviour (SA).

8.3 CONCLUSION

Overall it was agreed that workload and SA are not useful as starting points for the modelling process. However, it was agreed that both measures should be derived from model outputs in a form that can be related to rigorously defined constructs, so that they can be presented to stakeholders in a way that communicates complex constructs clearly. No rigorous definitions were agreed within the session, although it was accepted that workload is a measure of the amount of task activity that has to be completed per unit time and Situation Awareness encompasses the human quality of understanding as expressed in a predictive mental model as well as the hard measure of what information is available.

Chapter 9 – THE CONCEPT OF MODERATORS

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9.1 INTRODUCTION

The concept of moderators is based on the idea that there is a plausible 'datum' level of human behaviour that is modified by variations in internal state or the external environment. The modifications are frequently viewed as the primary source of human variability and, as such, have to be modelled in any nominally complete representation of human behaviour. The science of the impact of a range of environmental stressors has been the stock-in-trade of human science research for the past 60 years and some sophisticated models have been developed to explain human response to the stressful conditions. Even fairly simple cases can lead to considerable cost and complexity in implementation.

A barrier to the exploitation of Human Behaviour Representation in models for the analysis of systems and for supporting training applications is the cost of developing and validating the supporting elements. Developing a suite of models of moderators is a complex and expensive undertaking that involves a combination of physiological and cognitive models. Although many of the models are generic and can be reused, some components will be task specific and have to be tailored for each application, increasing the cost.

Do we have to be scientifically rigorous to develop models that are fit for purpose? Can we identify the number of internal states that we have to represent or can we approach the problem by using an argument that focuses on a single level of "arousal" to capture all stresses? Can we capture what we need by using a stochastic representation of human behaviour and rely on sensitivity analysis to draw our conclusions?

9.2 DISCUSSION

The term moderator is used to express any element in the simulation that can take different values on different occasions and that, through some route, affects human performance. To aid the analysis, moderators have been classified as external, internal or collective, defined as:

- ***External:*** Elements in the environment that can change the psychological or physiological state of an individual. Examples are temperature, clothing, imposed sleep/rest/work pattern, time of day, presence of a threat, or demand of an activity for work.

- ***Internal:*** Individual characteristics that can affect the psychological or physiological state of an individual, usually but not always in conjunction with an external moderator. Examples are height, weight, percentage body fat, gender, aspects of personality, experience, or level of training.
- ***Collective:*** Characteristics of the collective (or team) that can affect the state of interactions between the individuals who make up the team or collective. Examples are collective experience, nature of leadership.

The model of the action of external and internal moderators assumes that the moderating variable changes the psychological or physiological state of an individual and that this state change is what drives the change in behaviour or performance. State is therefore seen as dynamic within a simulation in that it changes with time. In general the internal moderators are viewed as “traits” and therefore fixed with time for a given simulation. There is a question of how many independent psychological or physiological states can be defined usefully. Early work on psychology identified a single state: arousal. For the purposes of modelling changes in performance or behaviour a number of states have been defined that relate to different moderators. Some states can clearly be affected by more than one moderator. Some examples are provided below.

Moderator	**State(s)**
Environmental temperature Clothing Height Percentage body fat Exercise level Drinking water	Core temperature Skin temperature Thermal comfort Hydration status Sweat rate
Exercise Food consumption	Blood glucose level Core temperature Skin temperature Thermal comfort Sweat rate
Time of day Prior sleep pattern Time zone history Work/rest pattern	Alertness
External threat Personality	Fear/Anxiety

A range of models has been developed that describe the effect of the environmental stressors on state. Examples are provided by sleep-loss fatigue models and alertness, or thermal models and body temperature. There is limited work describing the relationship between internal state and performance but some has been conducted (Belyavin & Spencer, 2004).

It is clearly possible to define physiological states that relate to external stressors. It is not as simple to isolate psychological states that relate to the “psychological” moderators such as personality, level of training, experience. Arousal has been used by psychologists for many years and appears to be a useful way of interpreting a number of effects. It is not clear whether fear or anxiety represents a distinct state or whether it drives arousal and affects performance by this route. A research requirement is the definition of the number of different states that need to be considered for the modelling of performance and behaviour and how these relate to the moderators of interest.

There is considerable discussion as to whether the problem of modelling more than one set of moderators simultaneously is more complex than modelling single moderators due to *interactions* between the associated states. An example would be the combination of the moderators that make up the thermal environment and those relating to sleep loss. If the sets of moderators do not interact, the effect of a change in alertness on performance or behaviour is not affected by current thermal status. Interaction implies that the different states affect the differing relationships between performance and behaviour. Preliminary investigation of a number of external moderators indicates that interactions of this kind may be present but are not large.

Andy Belyavin indicated that analysis at QinetiQ identified relatively few interactions between moderators, based on a review of the relevant literature. It was noted that interactions between internal and external moderators (flight strategy and fatigue) have been observed in basic research using computational cognitive models to study aircraft manoeuvring. Expert flight strategies, such as the control and performance concept for instrument flight, appear more fatigue resistant than novice strategies.

The challenge is to choose a minimally sufficient set of state variables and to model their impact on performance. There are a number of key questions.

- Could we use similar approaches to represent analytical physiological, cognitive and emotional processes?
- Are there valid models of individual states?
- What would be the potential interactions among the states?

Laurel Allender described how moderators are represented in IMPRINT (for more information, see: Allender, Salvi & Promisel, 1997). An engineering model is used based on performance data that defines a direct relationship between moderator and performance. The task is broken out over a taxonomy of lower level components such as gross motor movement, fine motor movement, visual perception, the components degraded and the outcome reconstructed from the components. The basis of the taxonomy is the mental or physical resource employed. For example in a decision making task the main resource would be the mental resource. It was observed that extrapolation from a data based model of this kind outside the range of the source data is not reliable and that more validity may be expected from a model that includes the intervening state and trait variables based on sound scientific relationships rather than mapping the moderator directly onto performance.

It was noted that the representation of moderators is linked to architecture because they form fundamental architectural constraints. Representing the effects of moderators in some architectures is difficult. The design of architectures should enable valid models of the effects of moderators to be incorporated.

There was a discussion of what was needed from modelling the effects of moderators. For training applications a view was expressed that plausible variation in behaviour was sufficient to meet the training need. The majority view of the meeting was that this is an ill-advised approach as it would result in TLAR (That Looks About

Right) validity that could easily fail for conditions only marginally different from the original design assumptions. Crude validity of this kind may be appropriate for narrowly focused applications, but for serious system analysis, general training or mission rehearsal where a broad spectrum of conditions could be anticipated, scientifically sound models and a higher level of validity are required.

9.3 CONCLUSION

Overall the meeting supported the argument that validated models of the effects of moderators are an essential component of all HBR applications. The approach involving external/internal/collective moderators related to internal states was endorsed in principle, although there was no agreement on an exhaustive list of either moderators or states. It was agreed that model architectures need to take account of modelling the effects of moderators explicitly.

Chapter 10 – COMPLEXITY, HIERARCHY, MODULARITY AND VALIDITY IN HBR ARCHITECTURES

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10.1 INTRODUCTION

In Chapter 8 of *The Sciences of the Artificial*, Herb Simon (1969) described the role of hierarchy in complex systems. Four key points include:

1) Complex systems are nearly always hierarchic;
2) Hierarchy facilitates evolution;
3) Near decomposability is an important characteristic of the hierarchical components of complex systems; and
4) Nearly decomposable, hierarchic structures facilitate comprehension.

In this session we considered HBR architectures from the perspective of nearly decomposable, hierarchical, evolutionary, complex systems.

10.2 SPEAKER PRESENTATIONS

Randy Jones, SOAR Technology Ltd.

Architectures and frameworks have higher level hypotheses and theories that govern them but there is a lot of devil in the detail. Modelling is often much more complex than frameworks suggest. To complicate matters, different architectures have different names for quite similar concepts, processes, and mechanisms. None of the architectures have all the mid-level constructs but they all have several similar key elements. Modelled tasks all have a somewhat similar knowledge structure across architectures. A shared meaning of terms and a common vocabulary would be useful in the community.

No architecture supports all basic representations and processes needed for all HBR needs. Randy expressed the need for a comparative framework to compare functions and features of all different architectures. To highlight the challenge, he noted that in Pew and Mavor (1998), major cognitive architectures are described in the words of the developers who use different terminology for fundamentally similar architectural components. Therefore, a deep understanding of each architecture is required to know which terms and functions are synonyms and which are not.

Randy described his interests and experiences in identifying similarities in processes and representations across cognitive architectures. His initial analysis included BDI, GOMS, and Soar. Randy published this initial work in AI Magazine in 2006. More recently he and colleagues at Soar, in collaboration with Christian Lebiere at Carnegie Mellon, developed an abstraction language called High-Level Symbolic Representation (HLSR) and have been investigating the use of HLSR to simultaneously generate Soar and ACT-R models of the same task. They see HLSR as part of their long-term strategy to create a modular, hierarchical implementation language that is useful for multiple architectures.

Dr. Emiel Ubink, TNO

Modular HBR: The many parts of a human model will in most cases be constructed as a nearly decomposable hierarchy, as described by Herb Simon (see introduction). It seems, however, that most behavioural architectures are an exception to this rule, at least at the functional or behavioural level. In most behavioural architectures several components (blackboard, rule based, etc.) have to be consulted to generate a specific type of behaviour, such as answering the telephone. This shows that on a functional level the behavioural architecture is not at all nearly decomposable. In Emiel's behavioural architecture based on pandemonium theory the components (demons in the pandemonium) are functional units ("behaviour chunks") instead of, for instance, units corresponding to the components in a theory of cognition. The demons in this pandemonium are in competition over a limited set of resources that represent the capabilities of the system and that are needed to generate behaviour. This results in a nearly decomposable system that simplifies the development of complex behaviour, that improves the maintainability, and that allows one to easily plug in or remove specific behaviours.

***Variability in Behaviour**:* Variability in behaviour has to do with action selection and action execution (i.e., which actions are taken and how these actions are executed). These "what to do" and "how to do it" questions are often addressed separately. They are, however, very much intertwined, especially with respect to human performance modelling. The answer to the "what" question could very well be influenced by the "how" answer (since I can not run fast enough I will not run at all) and vice versa (if I decide to move to location A, I will have to run). These "what" and "how" questions are so entangled because of the many feedback loops in behaviour, and because both the "what" and the "how" of behaviour depend for a large part on the capabilities of the modelled system, that should be viewed as a limited set of resources. The conclusion is therefore that when modelling human behaviour a way needs to be found to address both questions simultaneously.

A portion of Emiel's presentation focused on the relation of decomposability to validity. A fully decomposable architecture can be validated at the element level. This served as a nice segue into Robert West's presentation.

Dr. Robert West, Carleton University

Robert emphasized the point that evaluations of the validity of models and architectures are required in order to achieve objective, measurable progress in HBR. He and his colleagues at Carleton University are re-implementing ACT-R in Python using modular components that can easily be modified to change the system architecture. This facilitates modification and validation of the separate modules comprising the architecture. Python was chosen to ease code writing instead of using LISP, ACT-R's native language. To make progress, we need to show validity in the approach and the models developed, including predictive validity, but validation is an expensive process that the civilian market seems unwilling to assume. Without validation, we are left with curve-fitting and the best curve-fit solution isn't necessarily the one that captures the essence of the data best. Architectures, or rather models built in architectures, have to accurately predict human behaviour.

Robert expressed an interest in testing model fit against different datasets and established parameter values. Better ways of fitting model output to empirical data are also needed.

10.3 DISCUSSION

The general discussion focused primarily on modularity, common resources, and validity. Here are some highlights from the points and questions raised.

10.3.1 Modularity

Object oriented programming, service based software architectures, modular thinking (Randy mentioned aspect oriented programming) is the trend in all software development. The need for development of middle level constructs and functionality was raised by both Randy and Emiel.

10.3.2 Common Resources

Architectures for HBR need to be free and open source to promote reuse, particularly by academia, which is well positioned to address the validation question. There is a need to develop open, common agents that do things so that the community can explore them critically.

An on-line resource model-repository would be useful. The NATO RTO SAS 053 Virtual Institute for HBR came up in the discussion, but there was some confusion as to its status. Brian Gore pointed to the need for a place to publish new models. He mentioned a new journal coming out: the International Journal of Human Factors in Modelling and Simulation (Brian Gore is an editor), providing details much as the AMBR project did; NASA also has a book out covering model validation similar to AMBR but in a different context, possibly with a web-based repository also connected to it. Also the journal Cognitive Engineering and Decision Support was mentioned as a place to publish models.

10.3.3 Validity

It can be difficult to differentiate between a good architecture and a good model. How do you validate an architecture for predictive validity? Perhaps construct validity and content validity are sufficient for architectures unless some unique aspect of the architecture forces the model to predict a certain observation. Lots of successful models built in an architecture lends credence to its validity as an architecture, but you have to ensure that the models follow the tenets of the architecture and do not simply develop convenient shortcuts or work-arounds to simplify the model development.

Comparative validity is difficult in the context of architectures and HBR-based models because only the developers really understand the model implementations and approximations, and sometimes even the individual developers don't have a complete understanding of the entire architecture in sufficient depth. It is hard to compare models of the same phenomena if design decisions are not documented.

Can we validate architectures or can only specific models be validated? An architecture can only be validated through its use in many studies (i.e., validated on a meta-level). Evidence accrues for the validity of an architecture just as evidence accrues for the validity of scientific theories.

Validity, whether at the model level or the architecture/system level is not a binary state. Validation is a process of accrual of evidence and validity is a continuum rather than binary state that is context dependent.

10.4 SESSION RECOMMENDATIONS FOR HBR S&T

We need datasets from a wide and increasing range of tasks in order to objectively establish the broader validity of the cognitive architectures and HBR systems under development today.

Some type of middleware that facilitates cross-HBR comparison is advisable.

The HBR R&D community would likely benefit from a better understanding of productive methods for comparing models across architectures and comparing architectures.

Continuing the trend toward modular HBR systems and cognitive architectures is advisable.

10.5 SESSION RECOMMENDATIONS FOR NATO

There should be some interaction between SAS and HFM to explore potential for collaboration on HBR. The NATO RTO SAS-053 Virtual Institute for HBR, which was previously recommended by RTO SAS-017 panel, is due to wrap up in 2007, but information is required such as the timeline for standing up the Virtual Institute, its envisioned capabilities and suspected limitations. The Virtual Institute for HBR may provide a natural site for locating a repository of models and data that can be made public for modellers in the field.

Chapter 11 – FROM INDIVIDUAL TO GROUP BEHAVIOUR

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11.1 INTRODUCTION

Human factors are often considered at the individual level but military operations are typically a team effort. Early analytical simulation of large-team, force-on-force engagements (Lanchester, 1916) contained little that could be considered Human Factors. This trend seems to have persisted into more modern simulations despite an interest in small team activities within an operation. Even at the high aggregation levels, human aspects of collections of individuals such as morale and commitment are thought to play a significant role in areas of interest to Operations Research.

11.2 DISCUSSION

At the small team level (fire team, platoon, company, flight crew, squadron, etc.), individual Human Factors are still relevant (for example, workload, fatigue, thermal strain, etc.), however, other properties, characteristics and behaviours appear that experts feel are important to operation success (for example, morale, mutual support, commitment, etc.). While these are still attributes of individuals, they arise because of the interaction of the individuals in the team in their coordinated pursuit of a common goal. Other behavioural markers are also present in small teams that may be overlooked at higher levels of aggregation, but are important to capture for team simulation. These behaviours include communication and feedback, mutual support (backing up) and task sharing, team assessment and monitoring of teammates, to name a few.

Teams represent an additional level of complexity over individuals so it is reasonable to be concerned about appropriate representation when we have trouble modelling individuals, but if the degrees of freedom of the analysis can be controlled, and the subsystems suitably characterized, then team modelling seems feasible. Brad Cain suggested that the concern about the additional complexity doesn't necessarily follow as, by analogy, many aspects of fluid dynamics may be captured at a continuum level without modelling the dynamics of individual molecules. This reflects capturing individual HBR effects, such as workload, as team latent variables that can be considered factors at an aggregate level, much the same as viscosity reflects the exchange of momentum of molecules for fluids at a continuum level. Andy Belyavin remarked that individual representation may be necessary to detect certain phenomena but there should be nothing to restrict a mixture of aggregate and individual entities as long as the interaction phenomena are represented appropriately.

Team models can be conceived as a collection of cooperating individual models or as a team-entity that entails no distinct representation of its constituent members. Each representation approach has implications for the level of representation used and the human sciences requirements. Melanie Linde reported that some combination of these two approaches has been successfully used in Germany, where communication and group reasoning within teams has been represented as a “disembodied leader” construct. The “disembodied leader” – assumed to be a non-human, mechanistic process model – may preclude the interaction of operator states such as workload effects on group reasoning and leader activities. If timing is critical in the analysis, the disembodied leader approach also may cause problems representing where group knowledge lies within its member. It was also observed that “blobs” with disembodied leaders would not be appropriate for modelling the impact of complex interfaces. Nevertheless, the disembodied leader approach may be a suitable approximation when the desired level of granularity of the analysis is somewhere between a collection of individuals and the team entity level.

The collection of individuals approach allows more detailed models of the individual behaviours, capabilities and limitations. Conceivably, the collection of individuals approach can provide insight into why team performance is good or breaks down but this in turn requires more effort to model the interpersonal interactions; that is, the teamwork. But Rob West reported their observation that teamwork is often characterized by frequent interruptions and task switching, features that are not well captured by standard GOMS or task analytic approaches that focus on individual jobs. These analytical techniques, while capturing the task-work often fail to capture the team-work that leads to role and resource switching. Such phenomena might be better captured with a mixture of HTA and TNO’s pandemonium model, or some other task prioritization scheme, to reflect changing attentional foci of team members.

Laurel Allender suggested that dynamic network analysis might be a useful approach to capture interactions between team members as it measures both events and the content of any communications and enables analysis of communications in detail. The collection of individual models need to include the team tasks and include task scheduling that that dynamic network analyses captures to represent the ability or tendency of individuals to deviate from a plan in a constraint based system by opportunistic replanning.

The team entity modelling approach focuses above the level of the individual behaviours or abilities, and is the mainstay of many Operations Research military analyses. Rob West observed that details of the individual actions within the team by its members are typically ignored in organisational dynamics modelling. Organizational modelling is focused at a high-level of abstraction, examining the effects of performance variability, not why the performance actually degrades. The team entity approach loses some of the resource management constraints (such as cognitive workload) simplifying the modelling, but it introduces new latent variables that are team characteristics. These latent variables are often not formally defined – Are there representative models of how these latent teamwork aspects such as communication and situation awareness, perception and workload evolve with events?

There seemed to be a consensus that we can define the essential aspects of team performance that can be modelled and measured. Carol Cooper-Chapman reported that the UK has developed conceptual models of how some of these factors interact and the dstl work on STORM has explored social and cultural effects through formal models in the analysis of collective behaviour. There appears to be a need to delve further into the team research field to see if there are sufficient data that formal models can be further developed, establishing the distinction between Teamwork (interactions between team members that are an overhead) and Taskwork (individual work typically captured by GOMS-like analyses).

Team modelling might benefit from experimentation in games (such as DARPA's "Realworld[1]" and Breakaway's "A force more powerful[2]". Bob Foster noted that NATO has collective training centres that might be a good source of observational data to capture the interaction of different cultures in a team of individuals (command centre) or the cooperative activities of brigades from different nations.

It was thought that many of the aspects of crowds can be modelled at the fluid dynamics level. There has been some success in inserting beliefs and states into crowds to modify their behaviour. It was noted that crowds might be considered an extreme form of organisations and Old Dominion University (among others) has looked at the roles of individuals in the crowd. A military organisation might be represented as a hierarchy of small structured teams but the modelling problem area lies between these two extremes – "edge" organisations – where individuals in the crowd play roles as do small groups that might have a team attributes yet their interaction in the crowd entity is uncoordinated. Jerome Levesque described some preliminary work to develop a synthetic urban environment with crowd modelling to study and train for emergency response (discussion in section 4 below) that would benefit from data derived from observing domestic crowds (such as Old Dominion's research) as well as from NATO training centres if they engage in Effects Based Operations training.

11.3 CONCLUSION

There seemed to be a consensus that team modelling is viable with current technology. The HBR modelling community could, with some additional study, define the pros and cons of the various approaches to team modelling: capturing teams as blobs, collections of cooperating individuals or some combination of the two. Such a study would serve the M&S community, making recommendations about the suitability of each method for different purposes. Unfortunately, there doesn't seem to be a ready source of these pros and cons so some additional study is required to elicit this information from users of these techniques or by a team modelling panel. There was no indication of whether these approaches are affordable, but since many organizations are engaged in some form of team analyses, it would appear that some levels of representation are affordable. Validation of team models remains a tricky issue, although, as previously suggested by Lochlan Magee, transfer of training may provide a methodology for validation at some practical level.

11.4 SESSION RECOMMENDATIONS

1) Develop guidance to the M&S community on the appropriateness of various team and crowd modelling approaches to application areas.

2) Explore how task-analytical techniques can be extended to include teammork to support modelling teams as collections of individuals.

3) Document formal models that attempt to capture the effects of team and crowd latent variables on behaviour.

4) Explore using NATO training facilities as a source of data to support team modelling.

[1] http://www.darpa.mil/ipto/programs/real/index.htm

[2] http://www.afmpgame.com/

11.5 PRESENTATION SUMMARIES

CAMICS: Civilian Activity Modelling in Military Constructive Simulation

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This is a summary for a project that has started recently (June 2006). It is funded by the Centre for Operational Research and Analysis (CORA), a research organization part of Defence Research and Development Canada (DRDC). Our goal is to use the current knowledge in human behaviour representation and traffic modelling to implement a model of civilian population activity. The model will be used in constructive simulations for training and experimentation.

11.5.1 Aims

To develop a software model of civilian activity for military synthetic training environments, with a focus on urban areas.

To implement behaviours that are coherent with current literature and research in psychology and routing algorithms that reproduce basic urban traffic features.

11.5.2 Background

Simulations such as OneSAF, JCATS, and JSAF are currently used to represent a wide variety of traditional operational and war fighting scenarios. Recently, simulations have begun to be used to train for counter-insurgency, urban peacekeeping, crowd control situations, and other non-traditional operations. As a consequence, new models have emerged that attempt to simulate crowd and group behaviours (e.g., Crowd Federate™). Scenarios set in urban environments do not always involve crowd confrontation though. To our knowledge, none of the current models deal with normal daily activity, such as city traffic and busy street corners, or with crowd formation itself.

Existing crowd models often attempt to use "crowd psychology" as the basis for controlling simulated crowd behaviours. However, crowd psychology is mainly exhibited through varying levels of crowd aggression. The models track individuals within the crowd, but limit the behaviours depending upon initial group assignment (e.g., an agitator group). That approach cannot be applied to a model that would include normal daily behaviour, where each person remains driven by individual goals. Modern psychological research strongly suggests that each person maintains individual cognitions, personalities, and beliefs, (including religious and cultural ones), while engaged in group behaviours. Each person evaluates the nature of the sub-groups, the leadership, group structure and size, and continually examines possible situational factors that may influence their individual actions. This suggests that normal individual behaviours and group behaviours could be included in a single model.

In an urban context, human circulation by foot is coexisting with normal vehicle traffic. Fortunately, sophisticated models already exist to model vehicle routing, and the implementation of only a few basic rules should be enough for the training model we propose. On the software side, packages developed for the game industry, such as AI.implant™, now allow agent-based models of civilian activity to be built easily, including behaviour models and vehicle routing.

The project aims at providing the CF with proper models of civilian activity for constructive simulation environments, with a focus both on training and experimentation. It is a collaborative effort among the disciplines of psychology, computer science and military operational research.

11.5.3 Project Description

This project consists of two main branches:

1) Survey of current research covering individual versus collective behaviours, as well as urban traffic; and
2) Implementation of the models in a software simulation to use in constructive simulations.

The progress of these branches will overlap in time. It is planned that a working software prototype will be developed rapidly within the first few months of the study, and be improved subsequently as research progresses. The full research program would eventually span a 3-year period, each year adding an increment of functionality and reliability to the model, including an extensive validation process. In the first year it will be necessary to build the initial version of the software and implement basic behaviour and traffic models.

Chapter 12 – TECHNICAL EVALUATION REPORT

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12.1 EXECUTIVE SUMMARY

The Specialists' Meeting HFM-143/RSM on Human Behaviour Representation (HBR) in Constructive Modelling was held at the Canadian Forces College, Toronto, Canada from 30-31 May, 2007. The goal of the meeting was to obtain input from the scientific and operational communities regarding the validity of the recommendations made by the HFM-128 Task Group and to solicit input in those areas where the HFM-128 Task Group lacked experience. The meeting was organized around seven topic areas of importance in developing useful human behaviours:

1) What human factors does the operation involve;
2) Human task representation in M&S;
3) Behaviour generation – variability and choice;
4) Military relevant mental output measures;
5) The concept of moderators;
6) Complexity, hierarchy, modularity, and validity in HBR Architectures; and
7) From individual to group behaviour.

The structure of the meeting, with the focus on modelling issues rather than presentations on specific modeling tools or models, provided the forum and the time for a wide-ranging discussion of the many and complex problems and challenges faced by those involved in Human Behaviour Representation in constructive modelling and simulation. One of the central themes arising from the presentations and the discussions is the increasing need to incorporate a wide-range of Human Behavioural Representations into constructive simulations of complex, non-kinetic, operations involving a mix of military and civilian organizations. It is also apparent that there is a serious deficiency in tools for advanced model development, model sharing, simulation, and validation. To address these and other issues, NATO RTO should initiate a series of initiatives to:

1) Address the development of advanced modelling tools to expand the capabilities in simulating individuals, individuals within teams and organizations, and teams and organizations;
2) Develop new approaches to performance and behaviour metrics in large scale simulations and real-world operations;
3) Develop mechanisms to share data within the NATO community that has been collected from both small and large scale real-world operations, human-in-the-loop simulations, and constructive simulations, to aid in model development and validation; and

4) Develop technologies for large scale automated data reduction, analysis, and display, utilizing advances in GRID technologies.

12.2 INTRODUCTION

The Specialists' Meeting HFM-143/RSM on Human Behaviour Representation (HBR) in Constructive Modelling was held at the Canadian Forces College, Toronto, Canada from 30-31 May, 2007. The panel was organized by the Human Factors and Medicine Panel in coordination with the members of the HFM-128/ RTG.

Constructive simulation is becoming an ever more popular and powerful tool for use in Modelling and Simulation environments within NATO community. The representation of human behaviour and performance in these constructive simulations is a critical factor in the use of the technology to enhance the capability of the overall M&S environment. However, a large number of difficult and challenging issues surround the development and implementation of these representations. The purpose of the HFM-128 Task Group is to make recommendations on the implications of human factors and cognitive science to improve the implementation of human behaviour representations in complex simulations. The goal of the HFM-143 Specialists' Meeting was to obtain input from the scientific and operational communities regarding the validity of the recommendations made by the HFM-128 Task Group and to solicit input in those areas where the HFM-128 Task Group lacked experience.

In order to simulate discussions and to provide focused feedback to the HFM-128 Task Group, the meeting was organized around seven topic areas of importance:

1) What human factors does the operation involve;
2) Human task representation in M&S;
3) Behaviour generation – variability and choice;
4) Military relevant mental output measures;
5) The concept of moderators;
6) Complexity, hierarchy, modularity, and validity in HBR Architectures; and
7) From individual to group behaviour.

Formal presentations were relatively few and short. Instead, introductory comments by the Chair of each session were designed to stimulate discussion and feedback on the topics of concern. This technical review has attempted to focus on some general themes that emerged during the two days of discussion which suggest future areas of research focus for NATO RTO. Several specific topics for follow on Tasking Groups are identified.

12.3 SUMMARY

The first day of the meeting started with an introduction by Dr. Lotens, Chair of the HFM-128 Task Group and a Keynote address by Dr. Foster, Director, BioSystems, Office of the Director, Defense Research and Engineering, US Dept of Defense. The second day of the meeting was introduced with a second Keynote address, by Mike Greenley, Vice President of Modelling and Simulation, CAE.

Dr. Lotens' opening remarks provided a clear focus for the workshop, outlining the goals and the desired output to assist the panel in making recommendations to NATO concerning simulation of human behaviour in a military context. He reviewed the specific issues the workshop was hoping to address including some of the difficulties in modelling complex human behaviours:

1) Balanced human factors input to operational studies;
2) Generation of likely behaviours and selection of behaviour;
3) How to tailor models fit for purpose;
4) Performance metrics;
5) Reduction of complexity;
6) Reduction of effort; and
7) Reuse of developments.

He emphasized the need to develop the right model for the operator, at the right time, for the right cost.

Dr. Foster's keynote address focused on the challenges facing modelling and Human behavioural Representation given the broad range of scope, timelines, and complexity of tactical and strategic operations that are now undertaken by NATO countries still dealing with conventional and asymmetrical adversaries in the form of insurgency and terrorist operations, but more and more addressing issues of the non-kinetic battlespace with its complex socio-political issues, and interactions between military and civilian organizations who are dealing with the full range of security, stability, transition, and reconstruction (SSTR) issues. He also discussed the need for Human behavioural Representation to:

1) Extend beyond experimentation into areas of training, mission rehearsal, planning, and forecasting;
2) Expand the range of scenario and behaviour authorship to the user of modelling tools;
3) Incorporate the physiology of the operator rather than rely exclusively on empirically derived performance moderators;
4) Include complex social and cultural dynamics;
5) Develop better validation and verification approaches; and
6) Reduce the cost and time to create constructive simulations.

Dr. Foster identified three technologies that could assist this research and development: advances in gaming technology, supercomputing capability through cluster/grid based technology, and the development of open databases of real-world data to assist model development and validation.

12.4 SESSION SUMMARIES

12.4.1 Topic 1 – What Human Factors Does the Operation Involve?

Dr. Castor lead a discussion that addressed the problem of determining the level of fidelity, abstraction, and simplification of the real world that is appropriate for the modelling environment and for the particular model that is required. A major issue is determining what human factor issues should be incorporated into these simplified representations when dealing with the conflict between client needs and available modelling resources. A number of other issues were discussed including the lack of real-world data for modelling and modelling validation, and the need for highly trained, experienced modellers with multiple domain knowledge.

12.4.2 Topic 2 – Human Task Representation in M&S

Dr. Allender lead off the discussion with a review of the types of task analyses that are done on real-world systems to assist in the modelling environment, and outlined some of the issues in the representation of tasks: level of granularity in describing tasks, role of context in defining tasks, defining tasks for teams and large scale organizations, and the importance of natural language processing tasks. Dr. Vartanian's presentation on unconscious, naturalistic decision making and task performance in complex, rapidly evolving situations, lead to an extended discussion on the problems of incorporating such complex tasks, and the type of unconscious decision making involved in doing these task, into architectures for Human Behaviour Representations that have traditionally focused on rule-based approaches. The issues and difficulties involved in incorporating emotion and creativity were also discussed.

12.4.3 Topic 3 – Behaviour Generation: Variability and Choice

Mr. Armstrong introduced the session by discussing some of the requirements of Human behavioural Representation, citing the need for models that are more complex, flexible, plausible, and capable of extension and learning to supported unscripted behaviours, as well as demonstrate the wide variability of individual and team behaviours. Two presentations were given by Mrs. Cooper-Chapman and Mr. Emiel on modelling approaches that incorporate some of the concepts of variability and choice. The UK Combat System Engineering Model focuses on situational awareness, where the experience of the operator is a main modulator of behaviour, and the TNO model incorporates the impact of the external state of the scenario and the internal state of the operator on generating stress, along with the specifics of the task/mission to determine overall operator behaviour. Following the presentations there was extensive discussion on the approaches to use in large scale simulations and the inherent difficulties in bounding the variability within the behavioural representations. It was emphasized that the skill and experience of the modeller is a critical factor in developing appropriate simulations.

12.4.4 Day 2 – Keynote Address

Mr. Mike Greenley's Keynote address discussed the Human behavioural Representation issues from an industry perspective. He noted several major trends in the development of M&S technologies, including more commercialization of the tools and delivery of complete turnkey simulation environments to the end-user with continuous ongoing facility and simulation support by the contractors and the move to simulations involving a broader range of military and non-military activities, including complex multi-person teams, groups, and organizations. He stressed that more and more intelligent agent technologies will be used in the computer generated forces of the large scale simulations and identified the increasing role of the gaming industry and the advances in gaming technology in constructive and human-in-the-loop simulations. There was discussion following Mr. Greenley's address on the issues of surrounding the rapid delivery of simulation environments and the role of intelligent agents in accelerating the development of training capabilities.

12.4.5 Topic 4 – Militarily Relevant Mental Output Measures

Dr. Belyavin lead an extensive discussion on the metrics of Workload (WL) and Situational Awareness (SA) focused on seven questions:

1) Is Workload a well-defined construct?
2) Do we need to model it and if-so how?
3) Do we need to validate workload predictions from models?
4) Is SA a well-defined construct?
5) Can we validate measures of SA?
6) Is that a useful activity?
7) Are there other measures?

It was emphasized that there is often poor correlation of the metrics with task-performance, as well as the often poor correlation between the metrics generated by the cognitive architectures used for system models and the metrics obtained from the operators of the actual systems. There was agreement that most model architectures/environments are not designed to produce estimates of the metrics, especially SA, as they focus on performance prediction. Dr. Allender supported the need for reporting SA and WL metrics, as it provides the client with valuable information. There was a general consensus that the WL and SA constructs cannot be discarded, but more work is needed to better define and validate the SA construct.

12.4.6 Topic 5 – The Concept of Moderators

Dr. Belyavin also led a wide-ranging discussion on the moderators of human behaviour focusing on four specific questions:

1) For what applications do we need to solve the moderator problem?
2) Can we ignore moderators across a range of problems?
3) How do we develop valid models if we need to?
4) How do we deal with potential moderator interactions?

Though the impact of external stresses such as the environment are recognized as key moderators, much more extensive research and data is needed on other moderators, especially on the issues of:

1) Moderator characterization;
2) The interaction of moderators such as experience and personality type with other moderators such as the environment; and
3) Traditional and new definitions of moderators in the context of teams, organizations, and complex military and civilian operations.

It was emphasized that there is no simple "state" description of human capability. Rather, "state" is a complex function of task, training, personality, environment, etc.

12.4.7 Topic 6 – Complexity, Hierarchy, Modularity and Validity in HBR Architectures

Dr. Gluck introduced some of the issues surrounding the design and structure of the currently used cognitive architectures such as ACT-R and SOAR, emphasizing the slow pace of development of cognitive architectures and modelling environments. Dr. Jones' presentation on Comparative Analysis of Frameworks for Knowledge-Intensive Intelligent Agents, emphasized the lack of modularity of the architectures which would allow better reuse of model components, the difficulty in separating theory and implementation in the architectures, the inability to transfer cognitive models between architectures, and the difficulties in adding intelligent agent capabilities to the current architectures. He emphasized the need to follow a rigorous software engineering approach in building new architectures for intelligent behaviour that address understandability and usability challenges from the outset and which would include comprehensive support for necessary knowledge representations, and well-defined software components. He also outlined a long term strategy to meet these goals, that included the development of an abstract machine based on common functional components, interoperable object libraries as instantiations of abstract components, a formal framework to provide a bridge between science and implementation, and an ability to compose components quickly into the "best" architecture for a given task.

Dr. West's presentation examined the different ways of looking at a model's validity including face, model, predictive, architectural, and cross-model comparative validity and also emphasized the need to link the models back to the neural architecture of the brain. He also raised the difficulties of publishing and sharing the models. The presentations were followed by an animated discussion on how to address the shortcomings of the current architectures. There appeared to no consensus on how to proceed, though the current restrictions on model development and sharing were recognized.

12.4.8 Topic 7 – From Individual to Group Behaviour

Mr. Cain opened the session with a talk on the complexities and difficulties in extending models of Human behaviour to include group behaviours. He proposed three problem/discussion areas:

1) Can we define those essential attributes of teams that require formal models that would make team entity modelling viable and are validated formal models available?
2) Can we model teams of individuals at sufficient resolution and validate them for use in military simulations and what can make this process affordable?
3) Can we define the pros and cons of each approach sufficiently so that the military M&S community can make an informed decision about which is more appropriate in a given context?
4) How is an organization representation different from a small team and do we need to represent explicit EBO behaviours or is it sufficient to represent their "effects"?

Modelling teams as both individuals and collectives can be appropriate, however models of team leaders or intelligent agents acting to coordinate activities is a critical modelling issue. There is active research in crowd modelling, and socio-cultural team modelling, but model approaches for complex, non-kinetic mixes of military and civilian organizations is lacking.

12.5 COMMENTS AND RECOMMENDATIONS

The structure of the meeting, with the focus on modelling issues rather than presentations on specific modelling tools or models, provided the forum for a wide-ranging discussion of the many and complex problems and challenges faced by those involved in Human behaviour Representation in constructive modelling and simulation. One of the central themes arising from both Keynote addresses is the increasing need to incorporate a wide-range of Human behavioural Representations into constructive simulations of complex, non-kinetic, operations involving a mix of military and civilian organizations (both government and NGOs) and civilian populations, taking into account broad socio-political issues. It is also apparent that while more work is required on developing individual and team models, there is a serious deficiency in tools for advanced model development, model sharing, simulation, and validation – key factors in the development of useful simulations of large, complex systems. Modelling software technologies and database capabilities must be advanced to assist the community in rapidly developing, testing, validating, sharing, and using human behaviour and performance models that can be integrated into the full spectrum of M&S capabilities. It is also apparent that a generic component based approach to Human behavioural Representation is required that will facilitate a plug-and-play approach to implementing human models in large, complex constructive and HITL simulations involving system-of-systems. This effort will require the development of new modelling tools, as well as the embedding of HLA and other interfacing capabilities into existing technologies. NATO should focus less on human based experimentation, more on real-world data collection and the development of open-access databases, and more on development of general behavioural models that can be incorporated into a broad range of constructive simulations.

Though there is a desire to move authorship of simulations more and more to the client organizations, it must be recognized that the validity of the models are highly dependent on the training, skill, and experience of the modelers, who require domain knowledge in modelling theories and methodologies, in specialized software and programming languages, in mathematics and statistics, as well as in all aspects of the real-world situation they are attempting to simulate. When dealing with complex system-of-systems, the multi-domain knowledge requirements can be overwhelming. In spite of the advances in computing power, developing and using advanced Human behaviour Representations will remain an expensive and labor intensive discipline.

In order to enhance the development of Human behavioural Representations, and facilitate their incorporation into the larger M&S capabilities, NATO RTO should consider the establishment of several Working Groups to focus on specific raised by the Specialists' Meeting.

NATO RTO should initiate a series of initiatives to address the development of advanced modelling tools to expand the capabilities in simulating individuals, individuals within teams and organizations, and teams and organizations. This will require the integration of models of emotion and creativity and more emphasis on biological/physiological bottom-up models of brain function. One possible approach is develop human behaviour and performance models, using an open-source modelling tool such as Modelica, specifically designed for multi-domain, system-of-systems modelling, capable of handling a mix of mathematical representations, and allowing for the integrated modelling of humans, hardware, and communication components, as well as complex socio-political-economic systems This effort should also focus on developing tools for sharing models among different authoring tools by the development of XML schemas for model description and developing software to link multiple modelling technologies including Modelica, IPME, IMPRINT, SOAR, ACT-R, fuzzy-logic rule based systems, and neurophysiological based modelling environments such as PDP++/leabra++ .

In order to develop and validate performance and behavioural models, simulations and real-world experimentation there is a need to use well defined metrics, beyond the current individual Workload and Situational Awareness measures, which are difficult to define in individuals, and poorly defined in terms teams, groups, and networked operations. NATO RTO should establish Working Groups to develop new approaches to performance and behaviour metrics in large scale constructive simulations and real-world operations. Given the shear complexity of the large scale simulations of military and large scale civilian operations, this should include the development of technologies, including intelligent agents, for large scale automated data reduction, analysis, and display, utilizing advances in GRID technologies.

In parallel to the work on simulation, experiment, and real-world metrics, NATO should establish a Working Group on the issues of data collection and data storage, to handle the immense volume of data collected on human behaviour and performance. In addition to the issues surrounding raw data storage, the Working Group should address database methodologies for storing information on data collection methodologies used, data format and data conversion techniques, calibration procedures, and model databases.

Chapter 13 – CONCLUSIONS

13.1 SUMMARY

The two days of collegial discussions on Human Behavioural Representation issues seemed to be a successful forum for the exchange of ideas and exploration of concepts. The focus on plenary discussion with short presentations seemed to be well received and there was extensive participation in the discussions by all of the attendees.

There was general agreement with the points of view of HFM-128 approach to documenting the human factors of HBR and that the community seems to be on the right track. Although progress in modelling human factors has been slow over the past decade, other forums such as BRIMS[1] and the CogSci[2] conferences have been reporting a number of theoretical and applied papers on human behaviour and performance modelling. While we are still a long way from turnkey models of operators, the consensus that various modelling approaches are useful gives confidence to move ahead in the field from a variety of perspectives.

Situation awareness and workload are concepts that are intuitive to the military client, yet they are not necessarily useful as a scientific concept that should be modelled. However, metrics of such concepts may be generated by models to assist interpretation of the model's performance predictions.

A modular approach to modelling human activity seems to be the norm, lending itself to inclusion of moderators while attempting to simplify the complex field of human cognition. The human cognitive and performance modules benefit from an abstraction layer that is an interface between the modules and the modelled environment, allowing models to be reused across similar applications, requiring principally minor changes to the interface layer.

When going from individual HBRs to team and larger unit characteristics, one cannot simply link the models and expect to get plausible behaviour. There are additional behaviours and goals that characterize groups that need to be added to the model knowledge base.

[1] Behavior Representation in Modeling and Simulation: http://www.sisostds.org/.

[2] Cognitive Science Society: http://www.cognitivesciencesociety.org/cogsci.html.

13.2 RECOMMENDATIONS OF HFM-143 SPECIALISTS' MEETING ON HBR IN CONSTRUCTIVE SIMULATION

	General	To R&D Community	To NATO
1	Develop a capability to model non-traditional military activities such as humanitarian aid and state reconstruction. These activities are increasingly becoming the mandate of the military, OGD and NGO as a result of the 3-Block war concept and Effects Based Operations with the intent of predicting group and population reactions to events.	Develop formal modelling techniques to represent effects on organizations and populations as well as individuals that allow for generation and analysis of chaotic behaviours (small cause, large consequences).	Hold a joint meeting of SAS-053, HFM-128 and other interested parties to look for synergies arising from collaboration on HBR issues in NATO M&S with the intent of establishing a multidisciplinary panel to define the scope and requirements for constructive modelling of Effects Based Operations, including members from SAS and HFM currently working on HBR.
2	Advance the state of the art in HBR such that analysts can self-author behavioural models for CGF/SAFs.	Develop task representations that are compact in specification and show behavioural richness both by reactivity and proactivity. Continue the trend toward modular HBR systems and cognitive architectures to promote reuse and ease of refinement of models.	
3	Educate stakeholders in proper use of study design and analysis.	More exchanges between military customers of HBR and modellers to get an understanding of what is required from both perspectives. Clearly establish the constraints and approximations used in a model to determine the range of applicability, or its accreditation for use.	Organize a meeting in which military M&S stakeholders collaborate to integrate human factors into simulations. Develop a NATO checklist of human factors and document why each factor should be included as a means good practice, extending this into a guided interview that will help frame the model space.
4	Validate models and document their range of applicability.	Develop procedural and statistical methods of performing validation of models. Note best practices for gaining insight into behaviours and performance as well as techniques to quantify goodness-of-fit.	Collect and publish data that can be used to build and validate HBR suitable for military M&S.

	General	To R&D Community	To NATO
4		Establish public datasets from a wide range of tasks in order to objectively establish the broader validity of the cognitive architectures and HBR systems.	Promote the sharing of databases of behaviour and performance observations that can be used to shape models based on doctrinal procedure rules to promote more plausible behaviour. This could possibly be done in conjunction with the HBR Virtual Institute. Provide a mechanism to capture operational data that can be used to build and validate higher level models. Recommend the use of the NATO training facilities to collect data on high level C2 processes.
5	Develop a means of introducing plausible variability into HBR through the use of learning and the introduction of formal models that capture within and between individual variability or error.	Introduce factors such as learning (functional and procedural relationships), experience, context, goals and emotions into modelling operator performance. Define the different operator parameters that need to be considered for the modelling of performance and behaviour common for military operations. Define how these relate to the moderators of interest. Split sources of performance variation in traits (moderators, constant during the simulation period) and states (dynamic outcome based on state variables). Investigate if a similar approach to the successful use of state variables in physiological performance can be applied to states in the cognitive and emotional domains.	Assemble and make public an electronic library of moderator models and their effects on performance (preferably open source) that analysts can use in HBRs, providing validation details and suitable application of the models, possibly in conjunction with the HBR Virtual Institute.

	General	To R&D Community	To NATO
5		Develop or document formal models of emotion and motivation based on models from the social sciences that can be integrated within current HBR architectures.	
6	Development of an open source modelling environment that could evolve into an industry standard for the interface of HBR to other simulations.	Define the architectural constraints for implementation of state variables and performance shaping functions in the cognitive and emotional domains. Develop middleware that facilitates cross-HBR comparison. The HBR R&D community would likely benefit from a better understanding of productive methods for comparing models across architectures and comparing architectures.	Development of a hierarchical human HLA FOM or a similar interface specification that meets the foreseeable requirements of NATO's M&S activities. Document modelling synthetic environments, HBR architectures and models that currently support non-kinetic warfare, including social-cultural effects typical of post-combat reconstruction, noting extensions that would be required to make other products currently in use applicable to cost effective EBO simulations.
7	Improve the HBR element of team and group models.	Develop guidance on suitable means of modelling the way individual behaviour should be aggregated at team and larger unit level. Document descriptive, conceptual and formal models that attempt to capture the effects of team and crowd latent variables on behaviour. Develop guidance to the M&S community on the appropriateness of various team and crowd modelling approaches to application areas. Explore how task-analytical techniques can be extended to include teamwork to support modelling teams as collections of individuals.	Build upon NATO/RTO panel studies on teams and C2 modelling to identify formal models of teams and crowds as well as the latent factors that characterize groups.

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Appendix 1 – LIST OF PARTICIPANTS

A1.1 RTO HFM-128 HBR PANEL

			Nationality	Organization
Mr	Brad	Cain	CA	Defence Reaserch and Development Canada
Mr	Joe	Armstrong	CA	CAE Professional Services Inc.
Dr.	Wouter	Lotens	NL	TNO Human Factors Research Institute
Mr.	Emiel	Ubink	NL	TNO Human Factors Research Institute
Mr	Martin	Castor	SE	Swedish Defence Research Agency FOI
Dr	Andy	Belyavin	UK	QinetiQ CHS
Dr	Laurel	Allender	US	U.S. Army Research Laboratory
Dr	Kevin	Gluck	US	Air Force Research Laboratory

A1.2 HBR SPECIALISTS' MEETING PARTICIPANTS

Dr	Yuri	Fedulov	Belarus	Institute of Engineering Cybernetics
Dr	Lochlan	Magee	Canada	Defence Research and Development Canada
Dr	Peter	Kwantes	Canada	Defence Research and Development Canada
Dr	Vladimir	Zotov	Canada	Defence Research and Development Canada
Dr	Wenbi	Wang	Canada	Defence Research and Development Canada
Mr.	Brian	Gore	Canada	San Jose State University
Dr	Oshin	Vartanian	Canada	Defence Research and Development Canada
Dr.	Jérôme	Levesque	Canada	Defence Research and Development Canada
Dr	Robert	West	Canada	Carleton University
Mr	Bill	Fraser	Canada	Defence Research and Development Canada
Mr	Tab	Lamoureux	Canada	Humansystems Incorporated
Mr	Franklin	Lue	Canada	Defence Research and Development Canada
Dr	Barbara	Adams	Canada	Humansystems Incorporated
Mrs.	Luminita	Stemate	Canada	Defence Research and Development Canada
Mr.	Mike	Greenley	Canada	CAE Inc.
Mr	Paul	Kruszewski	Canada	Engenuity Technologies
Major	Melanie	Linde	Germany	Bundeswehr Centre for Transformation
Mr	Jonathan	Borgvall	Sweden	Swedish Defence Research Agency
Ms.	Sarah	Smith	United Kingdom	Defence Reserch and Technology Laboratory
Dr	Nicholas	Dingle	United Kingdom	Defence Reserch and Technology Laboratory
Mrs	Carol	Cooper Chapman	United Kingdom	Defence Reserch and Technology Laboratory
Dr.	Stephen	Goldberg	United States	US Army Research Institute
Dr.	Randolph	Jones	United States	Soar Technology
Dr	Robert	Foster	United States	Office of the Secretary of Defense
Dr.	Walter	Warwick	United States	Alion, MAAD Operation

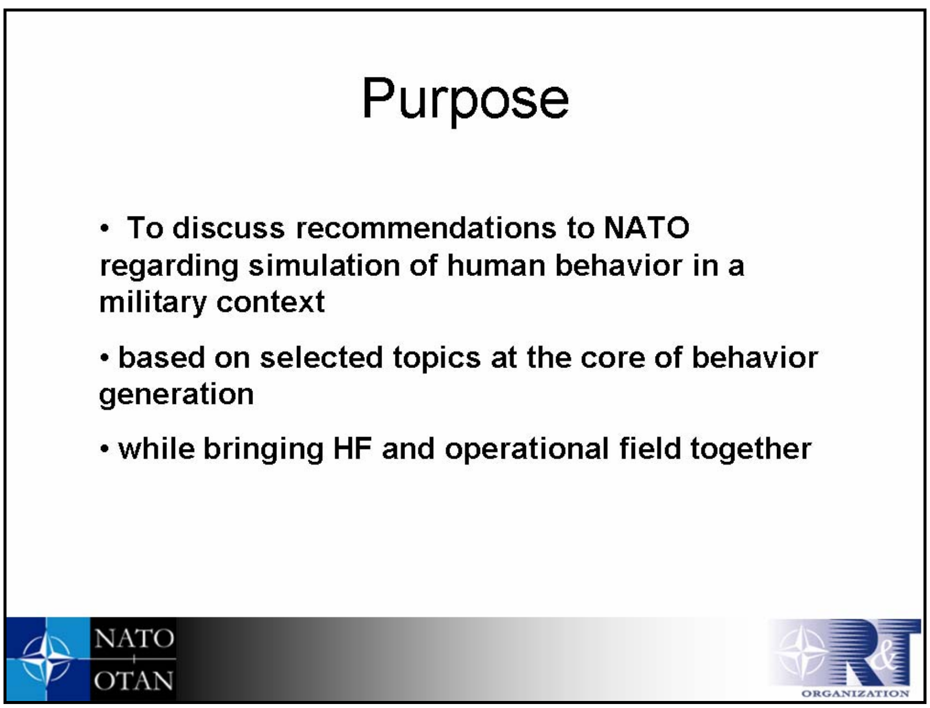
Appendix 2 – MEETING AGENDA

HFM 143 HBR Specialists Meeting Agenda
Canadian Forces College, Toronto, Canada
30-31 May 2007

Wednesday, 30 May		**Chair**	**Presentors**
8:30	Arrival, sign in, coffee		
9:00	Welcome, introduction	Brad Cain	
9:30	HFM128 Panel activities; HFM 143 Objectives	Wouter Lotens	
9:45	Keynote		Dr.Bob Foster
10:15	Coffee Break		
10:30	Topic 1: What human factors does the operation involve?	Martin Castor	Andy Belyavin
12:00	Lunch - Officers' Mess		
13:00	Topic 2: Human task representation in M&S	Laurel Allender	Dr. Oshin Vartanian
14:30	Coffee Break		
14:45	Topic 3: Behaviour generation - variability and choice	Joe Armstrong	Mrs. Carol Cooper-Chapman Mr. Emiel Ubink
16:15	Stretch		
16:20	Summary	Bill Fraser	
16:30	Wrapup	Brad Cain	
Thursday 31 May			
8:15	Arrival and coffee		
8:30	Keynote		Mr.Mike Greenley
9:00	Topic 4: Militarily relevant mental output measures	Andy Belyavin	Joe Armstrong
10:30	Coffee Break		
10:45	Topic 5: The concept of moderators	Andy Belyavin	Laurel Allender
12:15	Lunch - Officers' Mess		
13:00	Topic 6: Complexity, Hierarchy, Modularity, and Validity in HBR Architectures	Kevin Gluck	Dr. Rob West Mr. Emiel Ubink Dr. Randy Jones
14:30	Coffee Break		
14:45	Topic 7: From individual to group behaviour	Brad Cain	Dr. Rob West Chapman Dr. Jerome Levesque
16:15	Stretch		
16:20	Summary	Bill Fraser	
16:30	Closing words.	Brad Cain & Wouter Lotens	

Appendix 3 – PRESENTATION SLIDES

A3.1 HFM-128 CHAIRMAN'S MESSAGE



HFM 128 – HFM 143

- HFM 128 on HBR in constructive modeling to report in concept this summer
- Concept report is input to HFM 143. A separate report will be produced on the Specialist Meeting

NATO OTAN

Still a problem ....

- Balanced HF input to operational studies
- Generation of likely behaviors and selection of behavior
- Models fit for purpose
- Performance metrics
- Reduction of complexity, reduction of effort, reuse of developments

NATO OTAN

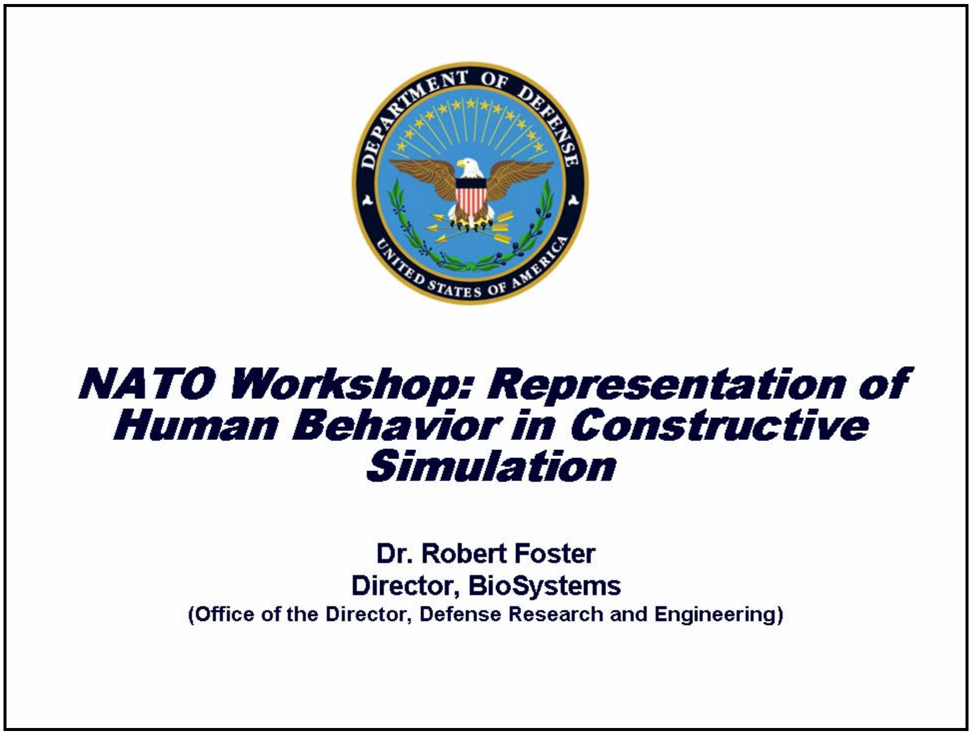
HFM 128 vision

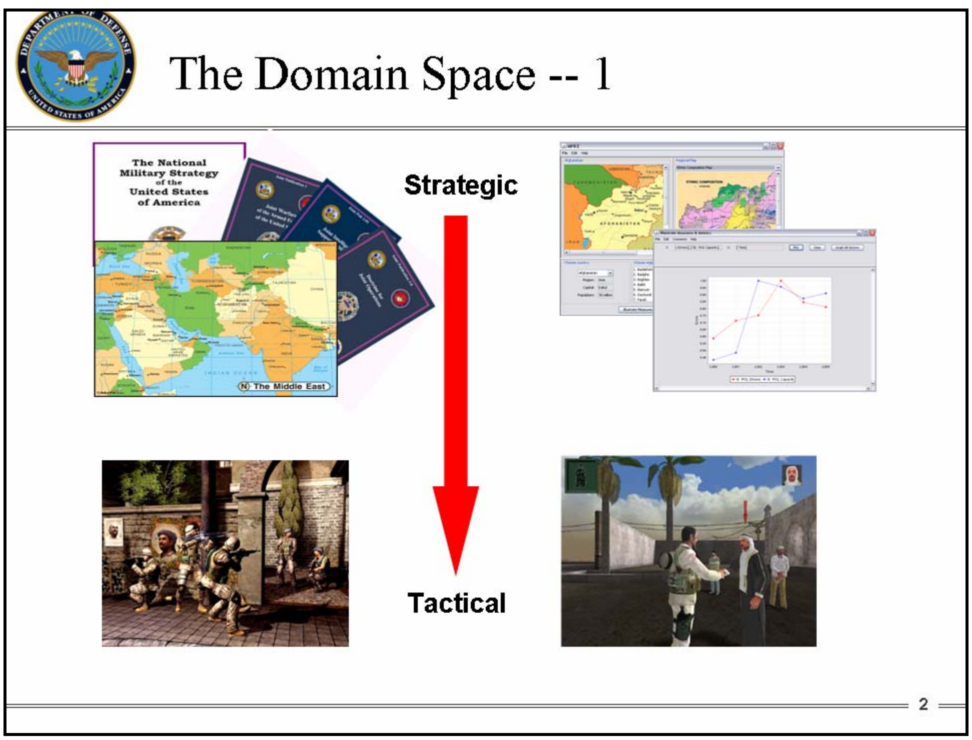
- Careful framing of a study
- Science based parameter choices
- Moderator concept to reduce complexity of HF
- Behavioral choices to generate course of action
- Performance in military perspective

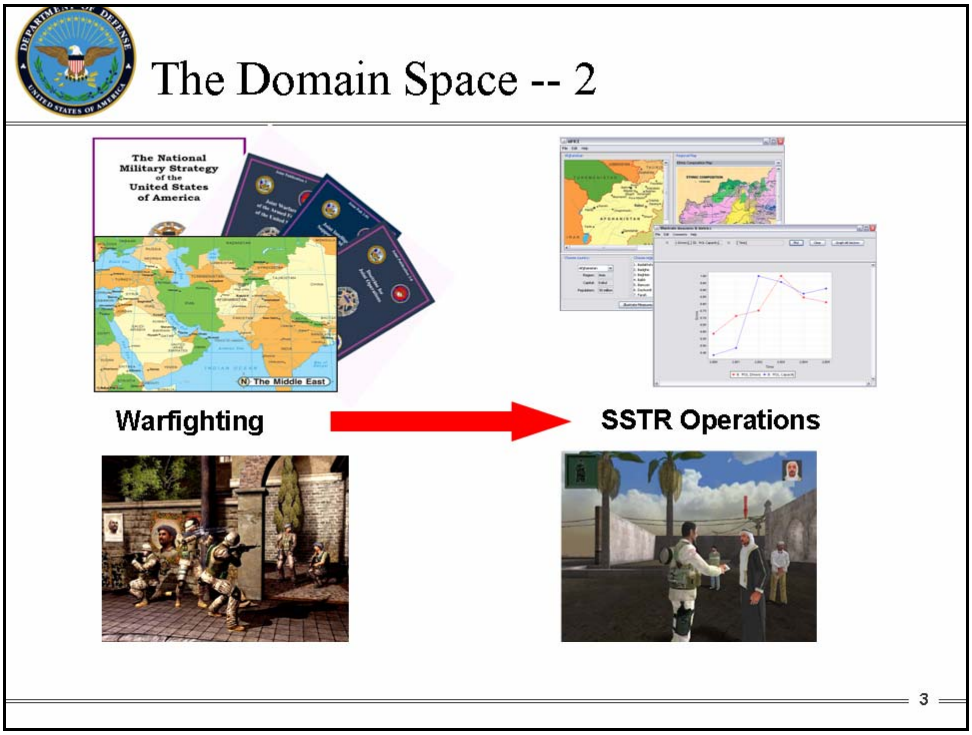
This meeting

- Selected topics
- Discussions introduced and steered by HFM 128 reps
- Notes and reporting.
- Your involvement is key

A3.2 KEYNOTE ADDRESS – DAY 1



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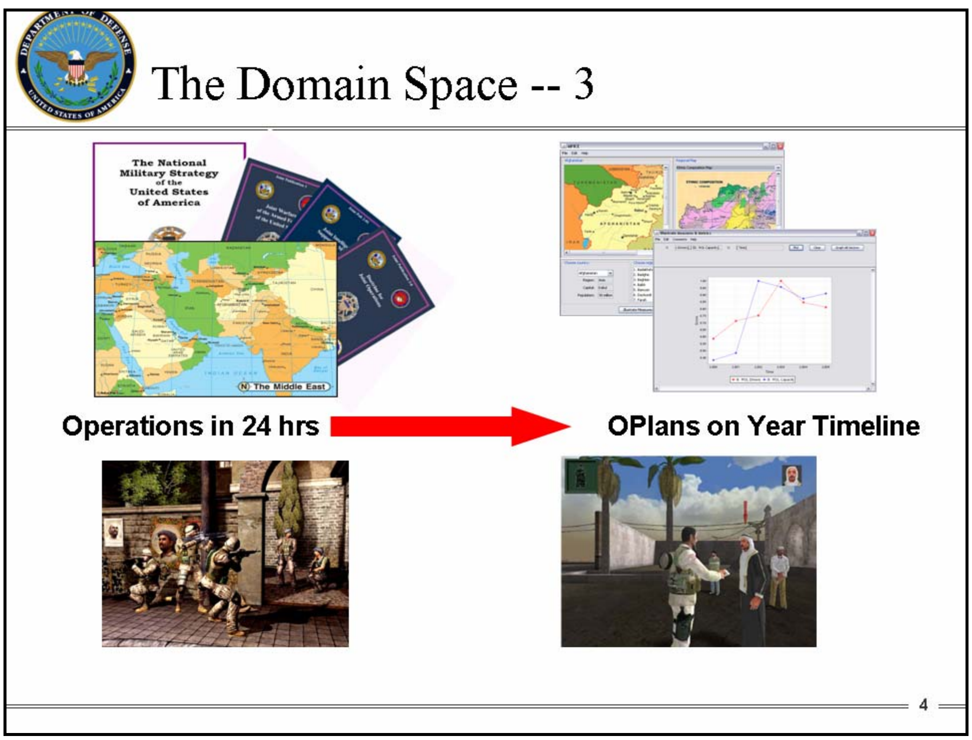
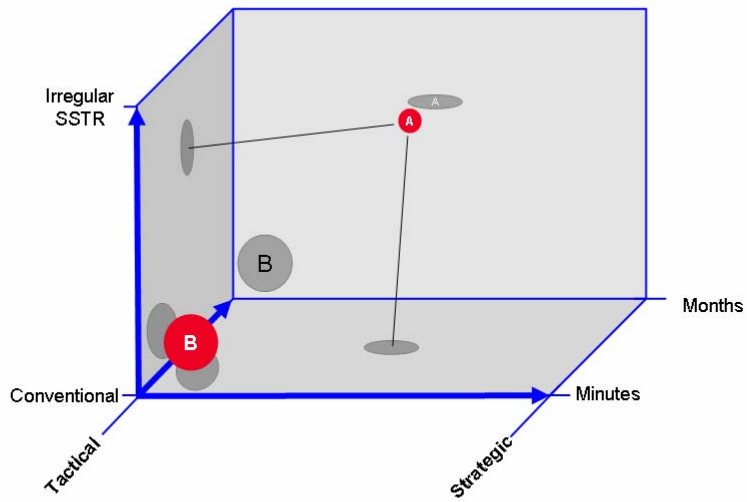
The National Military Strategy of the United States of America
The Middle East
Warfighting
SSTR Operations
3


The Domain Space -- 3
The National Military Strategy of the United States of America
The Middle East
Operations in 24 hrs
OPlans on Year Timeline
4

Domain Space and M&S Applications



5

Modeling Human Behavior

- Where is the current State of the Art?
  - Underlying science and theory
    - **Cognitive Theories/Modeling**
    - Human Performance Modeling
    - Physiological Systems
    - Emotional, Social and Cultural Theories/Models.
  - Supporting Technologies
    - High Performance Computing
    - Commercial Technologies
  - Challenges
    - Affordability
    - Flexibility
    - **Ease of Authoring**
    - **Flexibility**
    - **Verification**
    - **Validation**

6

Cognitive Theories/Modeling

- Cognitive Science and Theories:
  - The ‘Decade of the Mind’
    - DoD cognitive science investments are ‘stable’ in
      - Human-Computer Interface (Future Combat Systems, Helmet Mounted Display Technologies within Joint Strike Fighter, Navy DDG-1000)
      - Training and Simulation (Leadership, Socio-cultural awareness, etc.)
    - DoD investment in socio-cultural understanding and modeling is increasing
      - Recognition of need for broader understanding of socio-cultural factors from Phase 0 to Phase 4 of military operations
      - Security, Stability, Transition and Reconstruction (SSTR) operations
      - New Start program in Human, Social, Culture and Behavior Modeling

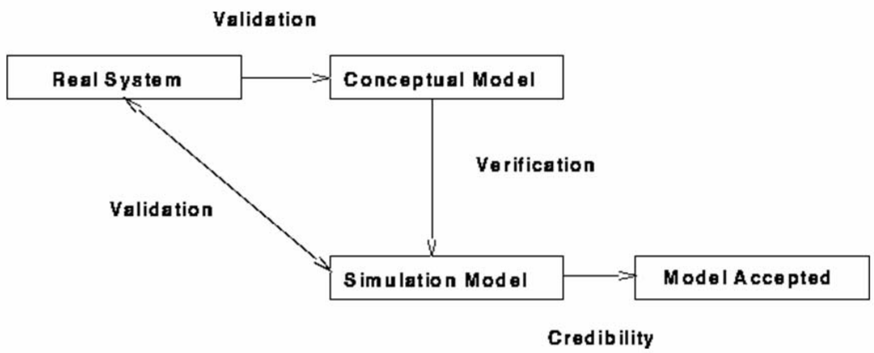
7

Ease of Authoring & Flexibility

- Focus is on transition of cognitive & behavioral models into systems/programs of record.
  - Need to be extensible beyond ‘Experimentation’
  - Training Systems, Mission Rehearsal, Planning, Forecasting
- We can’t have the modelers doing the ‘modeling’
  - To be successful, end user authoring tools must be developed
  - Must allow users to create entity behaviors, not just scenarios
  - Need to be able to understand, model and code general principles of behavior
  - Must decrease the manhours and cost to create simulations

8

Verification, Validation and Credibility



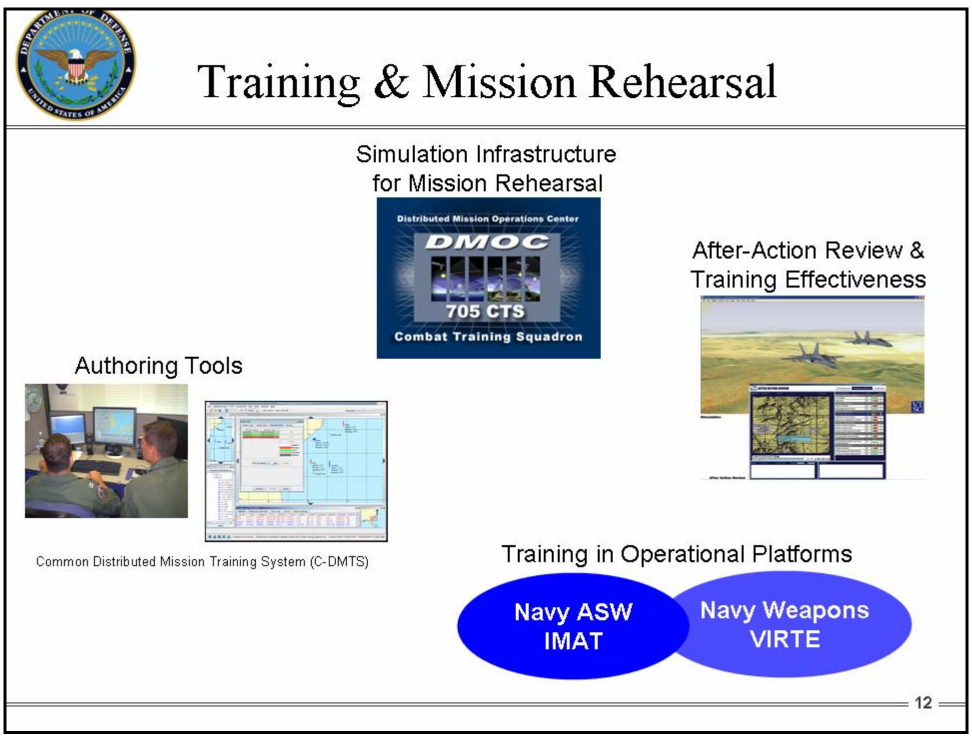
9

Verification & Validation

- Verification
  - There is a proliferation of models and simulations that go straight to use without V V & A
  - Lack of proper documentation
  - Lack of empirical analysis
- Validation
  - Face validity vs. Structural/Predictive validity
    - Going beyond SME-based assessments
    - Going beyond the existing range of parameters
    - Many models are not empirically testable
  - Structure vs. Content
    - Frameworks and architectures often come first
    - Some frameworks can be used as testbeds for demonstration and validation
- Credibility
  - When the real world is poorly understood…then the conceptual model is poor and it may be verified, not valid AND not credible
  - Need for effectiveness measures

10

There Are Some Successes, I Think



Are There Testing Environments ?

Traditional M&S

- SEAS
- ??

Games

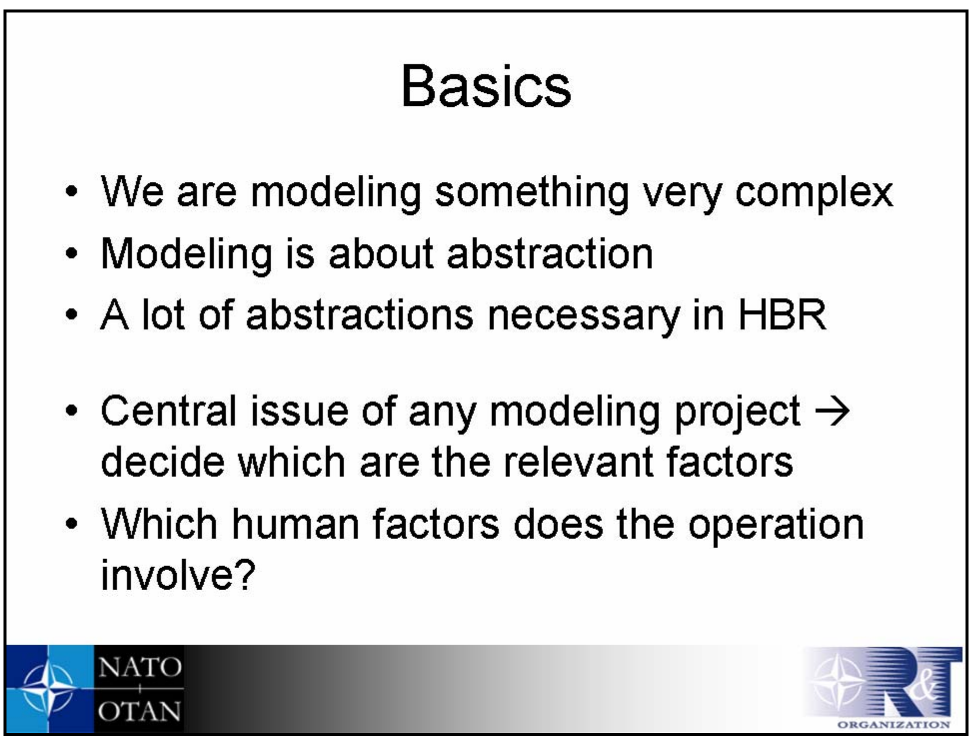
- RealWorld
- "A Force More Powerful" (BreakAway Ltd)
- ??

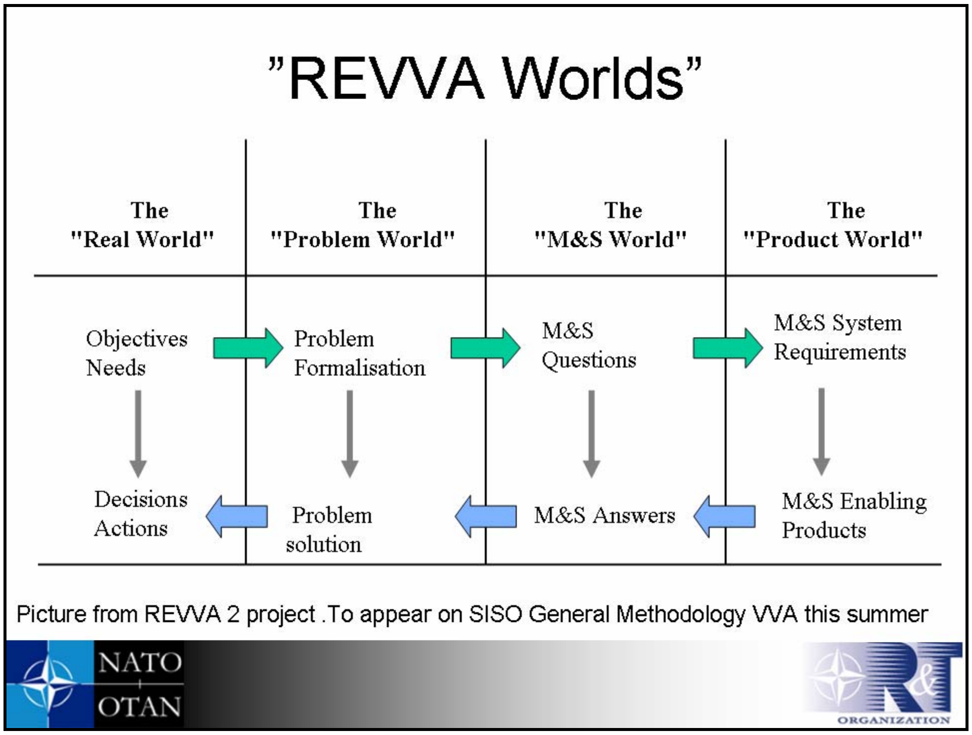
13

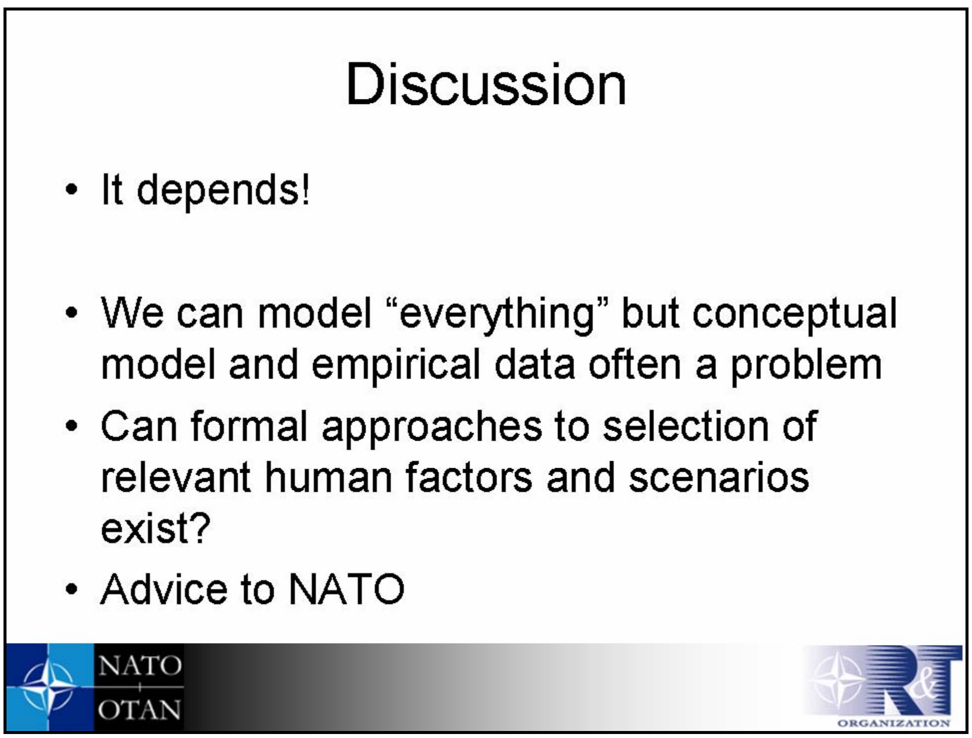
In Summary There Are Challenges

- Authoring
  - From real experiences
  - Application Users (not experts/"pucksters")
- Behaviors
  - Include actual physiology (not just "moderators)
  - Include human social & culture dynamics
- Validation
  - Data
  - Datasets for research and developers

A3.3 WHAT HUMAN FACTORS DOES THE OPERATION INVOLVE?




”REVVA Worlds”
The "Real World"
The "Problem World"
The "M&S World"
The "Product World"
Objectives
Needs
Problem
Formalisation
M&S
Questions
M&S System
Requirements
Decisions
Actions
Problem
solution
M&S Answers
M&S Enabling
Products
Picture from REVVA 2 project .To appear on SISO General Methodology VVA this summer
NATO
OTAN
ORGANIZATION


Discussion
• It depends!
• We can model “everything” but conceptual model and empirical data often a problem
• Can formal approaches to selection of relevant human factors and scenarios exist?
• Advice to NATO
NATO
OTAN
ORGANIZATION

Questions

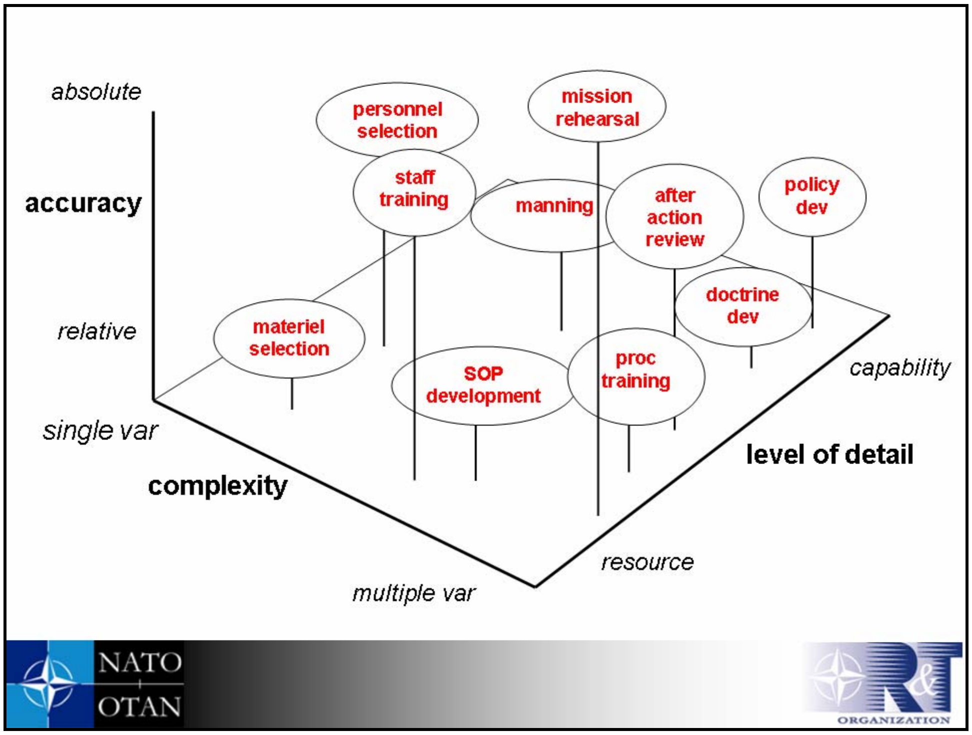
- How to link customer higher level questions, e.g. sustainability of force, to requirements for which HF to include?
- How to choose the appropriate fidelity level for representation?
- How to do trade-offs between level of detail and budget?

NATO OTAN · R&T ORGANIZATION

Questions

- Traceability and explainability of behavior are very important, but does this lead us to choose too simple scenarios?

NATO OTAN · R&T ORGANIZATION


absolute
accuracy
relative
single var
complexity
multiple var
resource
level of detail
capability
personnel selection
mission rehearsal
staff training
manning
after action review
policy dev
doctrine dev
materiel selection
SOP development
proc training
NATO
OTAN
ORGANIZATION


Modelling Low Flying Activity
NATO Specialist Meeting
Toronto May 30 2007
Andy Belyavin, QinetiQ
NATO
OTAN
ORGANIZATION

Representing human factors

- Choice of what human factors need to be represented is an important decision in any study
- By way of illustration I will describe a study involving a complex two part model
- An early decision was made to limit the human factors detail
- Was it right?

Study Objectives

- Basic principle operated in the UK low flying system (LFA) is “See and Avoid”
- Responsibility lies with aircraft flying in the system to detect potential conflicts visually and take appropriate action
- Primary aim of the study was to identify the effect of measures that could reduce random collision rate

Approach adopted

- Clearly human factors in collision avoidance
  - Visual detection
  - Avoidance action
- Possible human factors in flight tracks….
- Since intersections between tracks are random decided that no need to describe HF in flight pattern
- Could split the model into two parts:
  - Track & intersection generation
  - Given track geometry can the potential decision be detected?

NATO OTAN

Track generation

- Track generation is not simply set of tracks in arbitrary directions
- Intersections are a "squared" problem (n*n)
- Low flying area has some flow control influencing local density
- Traffic (Military & Civilian) has different altitude patterns

NATO OTAN

Generation Model

- Model constructed of traffic in LFA according to observed data on patterns
- Careful construction so that traffic density would conform to observations
- Generate a series of potential conflicts
- Define the geometry of the conflict in terms of directions/angles/aircraft types
- Validate conflict rate against observations

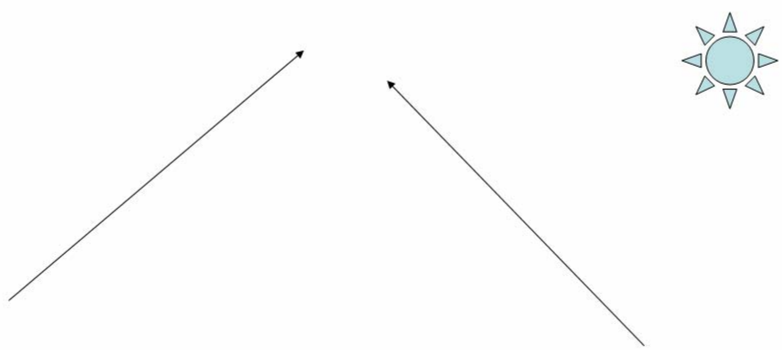
Validation basic model

- For Military/Military and Civil/Civil conflict rate validated satisfactorily against reported air prox. Reports
- Military/Civilian was not consistent with observations or with the other categories
- Indications of over-reporting

Collision geometry

- Visual detection of a potential collision depends on 4 aspects
  - Target contrast
  - Target size
  - Effective approach rate
  - Number of observers

Collision geometry

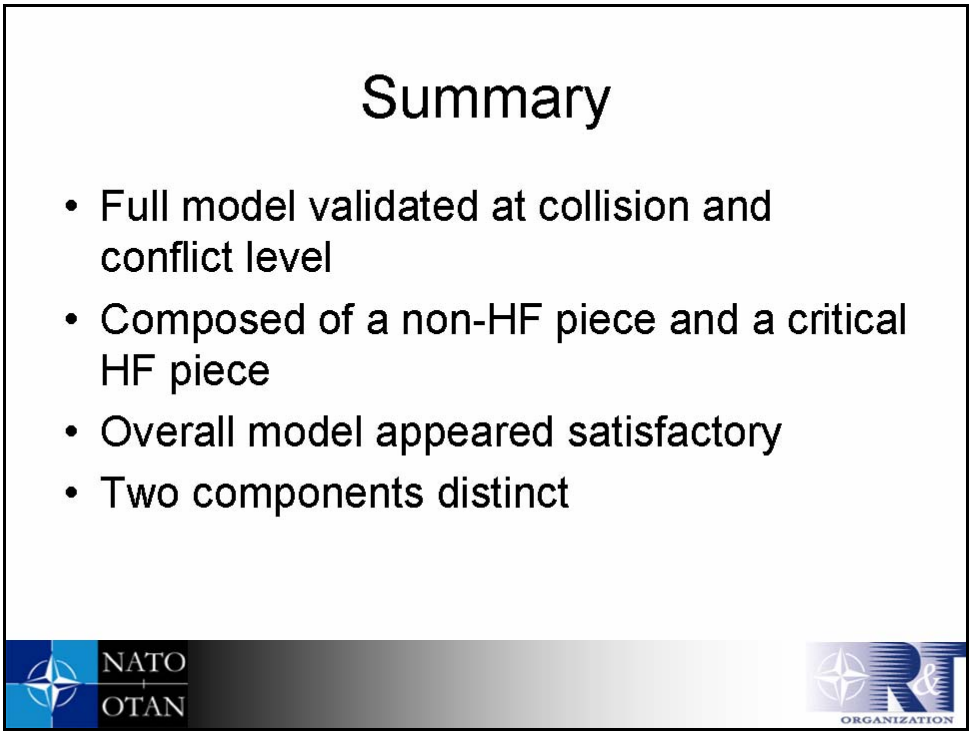


Visual detection

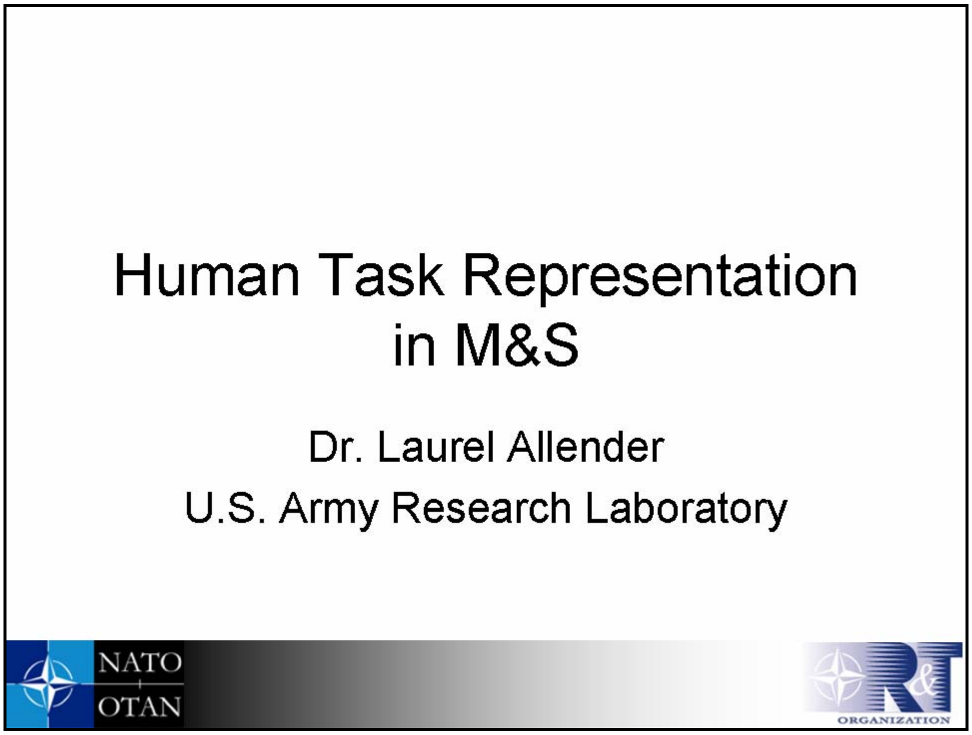
- Visual detection further depends on
  - Time of day
  - Day of year
  - Geometry relative to solar position

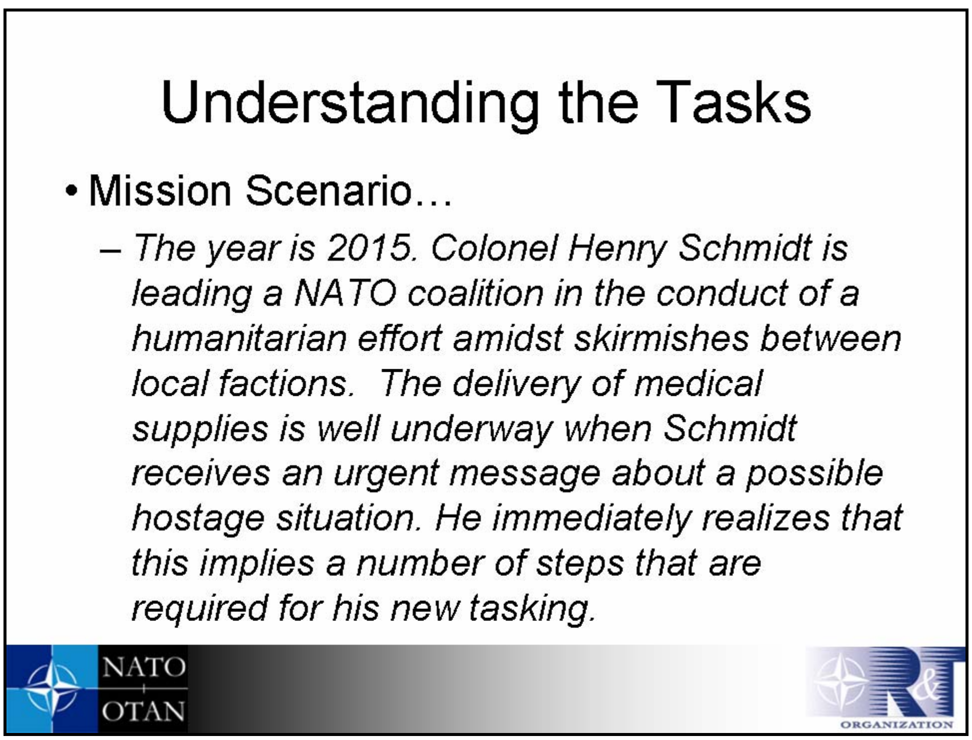
Full model

- Generate conflicts using first model run for 100 years
- Use HF visual detection model to assess probability of detection a prescribed number of seconds from impact
- Can vary assumptions about detection aids and compare
- Use baseline to validate model


Summary
• Full model validated at collision and conflict level
• Composed of a non-HF piece and a critical HF piece
• Overall model appeared satisfactory
• Two components distinct
NATO
OTAN
ORGANIZATION

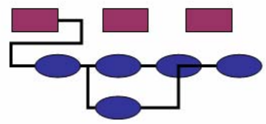
A3.4 HUMAN TASK REPRESENTATION IN M&S





Understanding the Tasks for M&S

- Task Analysis
  - Starting point for human factors efforts
  - Military regulations describe/perscribe task analysis
  - Types of task analyses
    - Cognitive
    - Goal directed
    - Hierarchical
    - Work-centered…



NATO OTAN

Understanding the Task: ”Secure the Building”

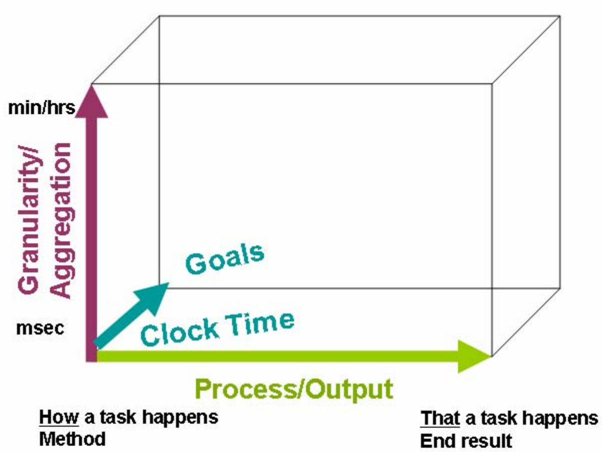
- The Army surrounds the building with defensive fortifications, tanks, and concertina wire.
- The Marine Corps assaults the building using overlapping fields of fire from all appropriate points on the perimeter.
- The Navy turns out the lights and locks the doors.
- And the Air Force takes out a three-year lease on the building with an option to buy.

NATO OTAN

So, What Must Be Considered to Represent Human Tasks in M&S?

- What level of task granularity or aggregation is appropriate?
- At what level or under what circumstances is it sufficient to represent the end state of task performance? Should the underlying process that generated the performance be represented?
- How much context must be specified?
- Can we create an engine that allows us to give high-level commands to the model?
- Is natural language understanding a desired or necessary capability for human behavior representations?

Task Representation Considerations



- Where does context specification fit?
- Learning?
- Natural lanuage commands?

- How does this vary for concept exploration, design, training, or mission rehearsal?

DEFENCE R&D DÉFENSE

Role of Conscious Deliberation in Simple vs. Complex Tasks

Oshin Vartanian
Defence Research and Development Canada

Defence Research and Development Canada   Recherche et développement pour la défense Canada   Canada

Problem

- How is a task (e.g., a command) represented?
  - e.g., "Secure the building!"
  - Explicitly vs. implicitly?
- How does <u>conscious</u> deliberation affect representation?
  - Conscious deliberation = attention
- Key Question: Is conscious deliberation always advantageous?

Defence R&D Canada – Toronto • R & D pour la défense Canada – Toronto

Problem (cont.)

- Classical wisdom:
  - Conscious deliberation↑ ⇒ quality of choice ↑
  - Time pressure/anxiety ⇒ quality of choice↓
- Is this true for tasks of varying complexity?
  - Complexity = Number of attributes

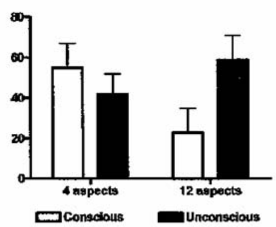
Problem (cont.)

- Complex tasks have many attributes
  - e.g., "Secure the building!"
    - Time
    - Space
    - Sequencing of actions
    - Cost and benefit of engagement
    - etc.

Problem (cont.)

- Key insight: Value of conscious deliberation is a function of complexity:
  - Simple tasks (e.g., buying shoes) ⇒ value↑
  - Complex tasks (e.g., choosing a car) ⇒ value↑

Quality



Dijksterhuis et al. (2006)

Fig. 1. Percentage of participants who chose the most desirable car as a function of complexity of decision and of mode of thought ($n = 18$ to 22 in each condition). Error bars represent the standard error.

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Problem (cont.)

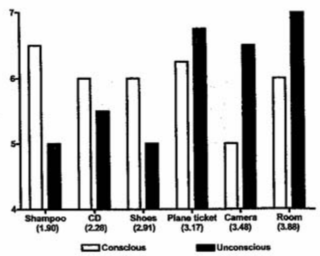
- Conscious deliberation:
  - Limited capacity
    - Attention can be directed at few attributes
  - Rule-based (e.g., don't exceed a certain price)
- Unconscious (implicit) deliberation:
  - Geared toward pattern recognition
  - Not limited by capacity

Defence R&D Canada – Toronto • R & D pour la défense Canada – Toronto

Problem (cont.)

- Upshot? Deliberation will not help if task is complex
- This is true in terms of:
  - Objective quality of choice
  - Post-choice satisfaction

Satisfaction



Dijksterhuis et al. (2006)

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Implications: Operations

- Training is key!
  - Must facilitate pattern recognition.
  - Command carried out without deliberation.

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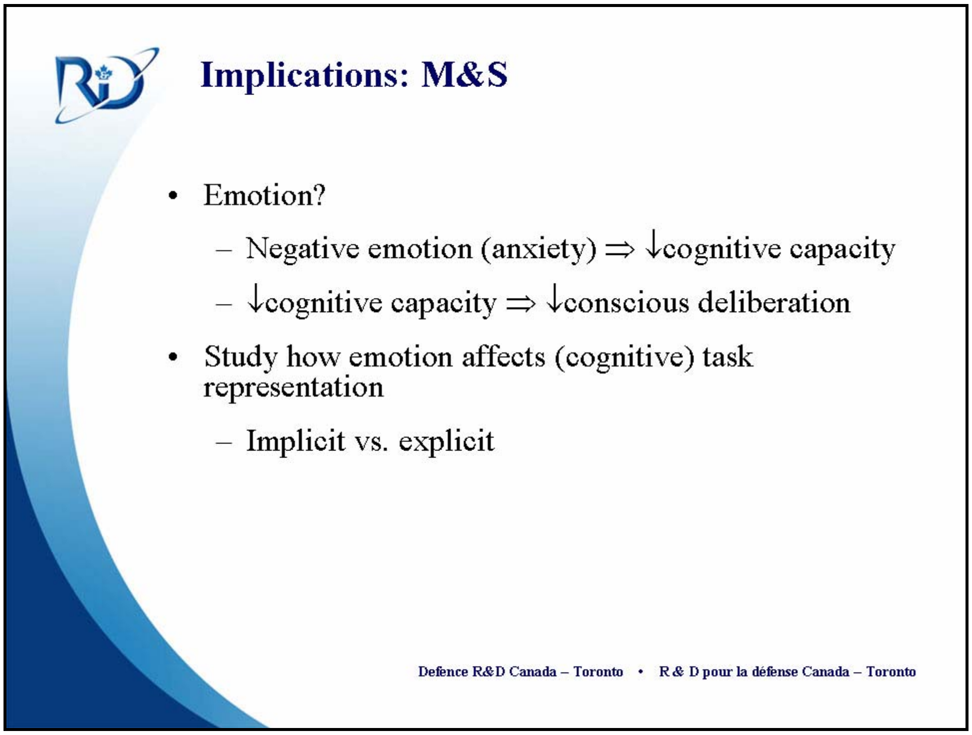
Implications: M&S
• Emotion?
– Negative emotion (anxiety) ⇒ ↓cognitive capacity
– ↓cognitive capacity ⇒ ↓conscious deliberation
• Study how emotion affects (cognitive) task representation
– Implicit vs. explicit
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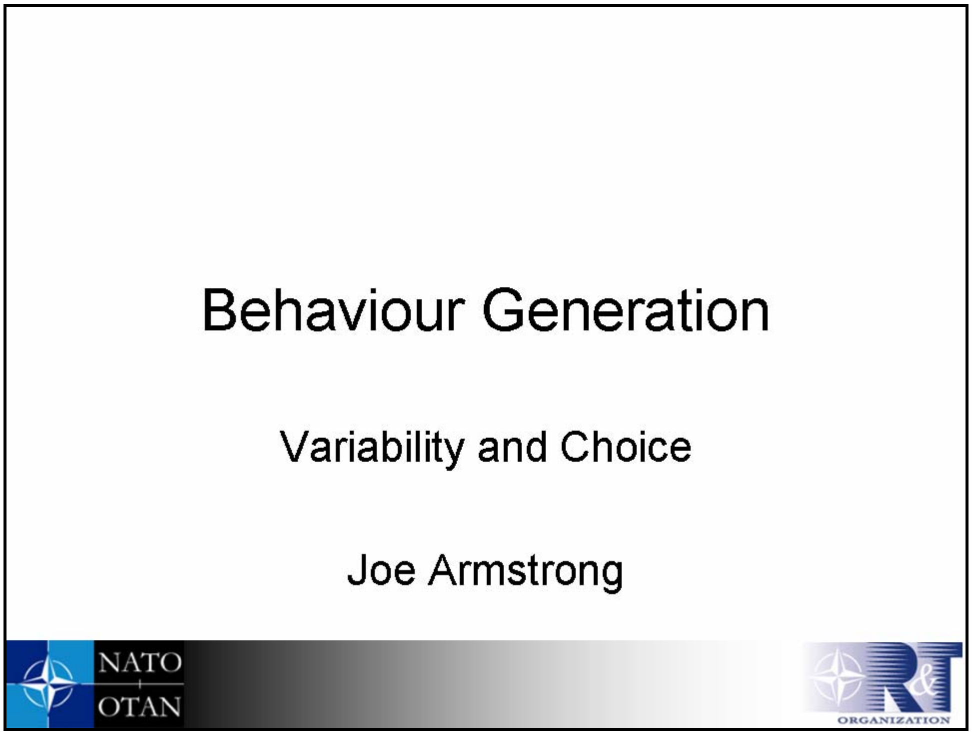
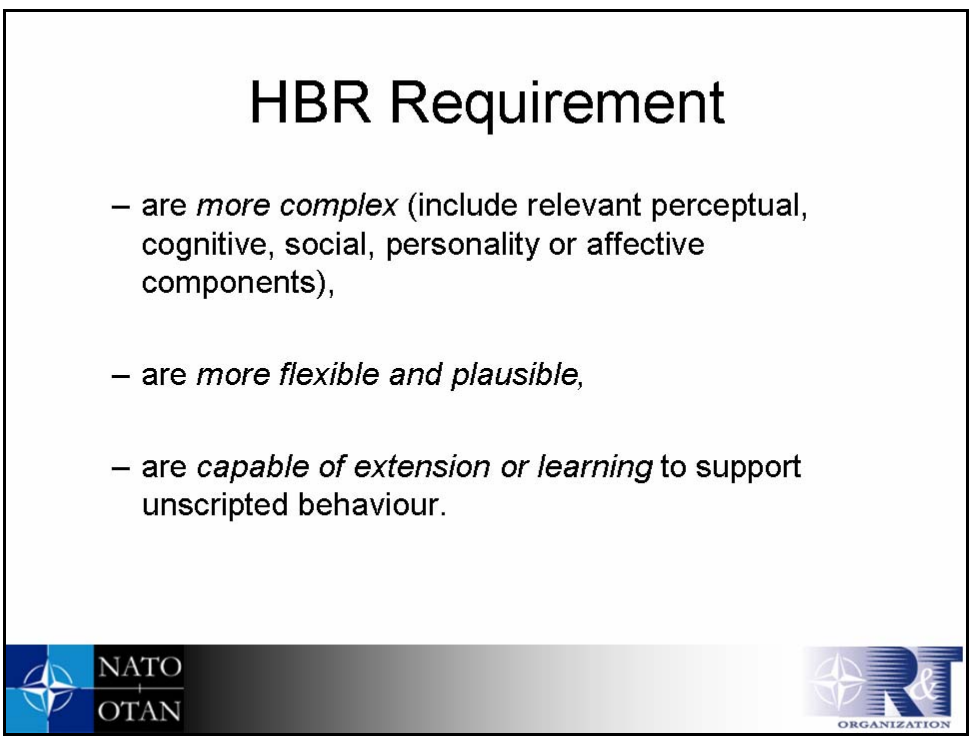
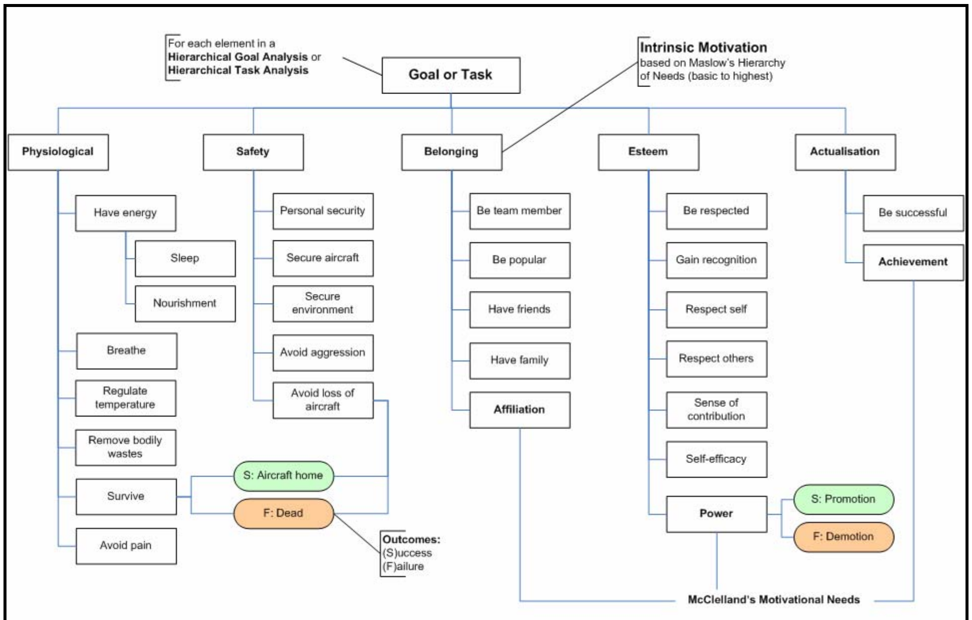
A3.5 BEHAVIOUR GENERATION: VARIABILITY AND CHOICE





Variability

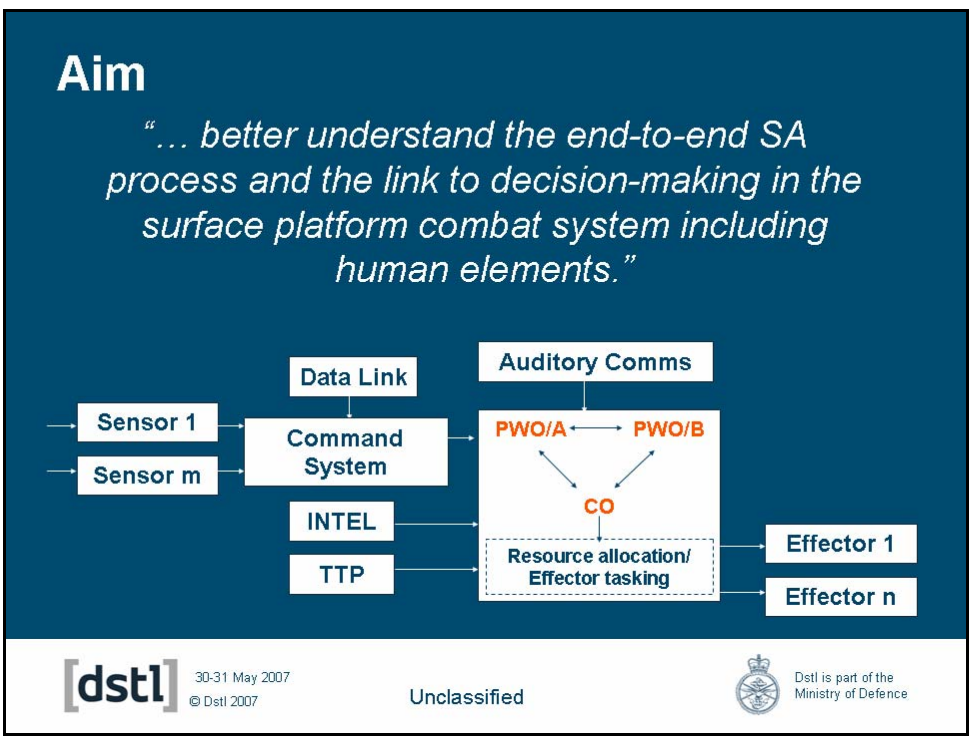
- Sources of Variability
  - Trait Characteristics
    - Physiology
    - Anthropometry
    - Personality
    - Socio-Cultural Factors
  - Environmental Factors
    - Time of day
    - Temperature
    - Vibration
  - Behavioural Characteristics
    - Task Selection
    - Task Alternatives



Discussion

- Existing analysis techniques
  - Development & Acquisition Support
  - Concept Exploration
- Integration within models
  - Behavioural alternatives
  - Behavioural drivers
  - Link between source of variability and cognitive activity
- Characterization of behaviour
  - Individual vs. group
  - Relationship to error
  - Military vs. Civilian


CSEM
Combat System Engineering Model
HFM-143: 30-31 May 2007
Carol Cooper Chapman


Aim
"… better understand the end-to-end SA process and the link to decision-making in the surface platform combat system including human elements."
Data Link
Auditory Comms
Sensor 1
Sensor m
Command System
PWO/A
PWO/B
CO
INTEL
TTP
Resource allocation/ Effector tasking
Effector 1
Effector n
30-31 May 2007
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Behavioural Variability

Where does behaviour come from?

Data driven – primarily bottom-up:

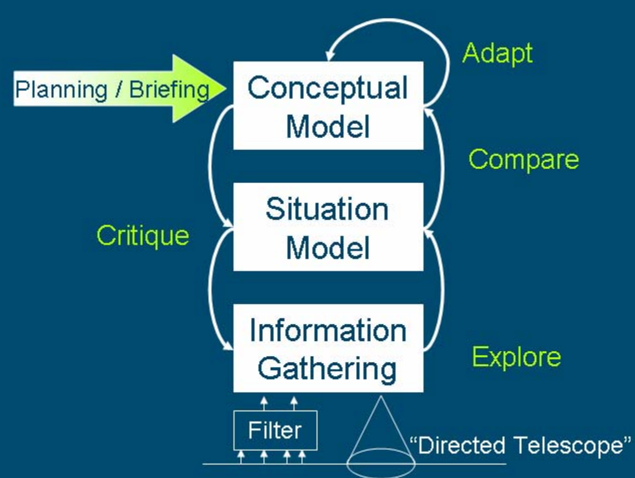
- OODA loop (Boyd)
- Endsley's (1995) SA model

Experience driven – primarily top-down:

- CECA loop (Bryant et al., 2004)
- RPD Model (Klein, 1993)
- Decision ladder (Rasmussen, 1993)

[dstl] 30-31 May 2007 © Dstl 2007 Unclassified Dstl is part of the Ministry of Defence

Top-down: CECA Loop



From Bryant et al. (2004, p.109)

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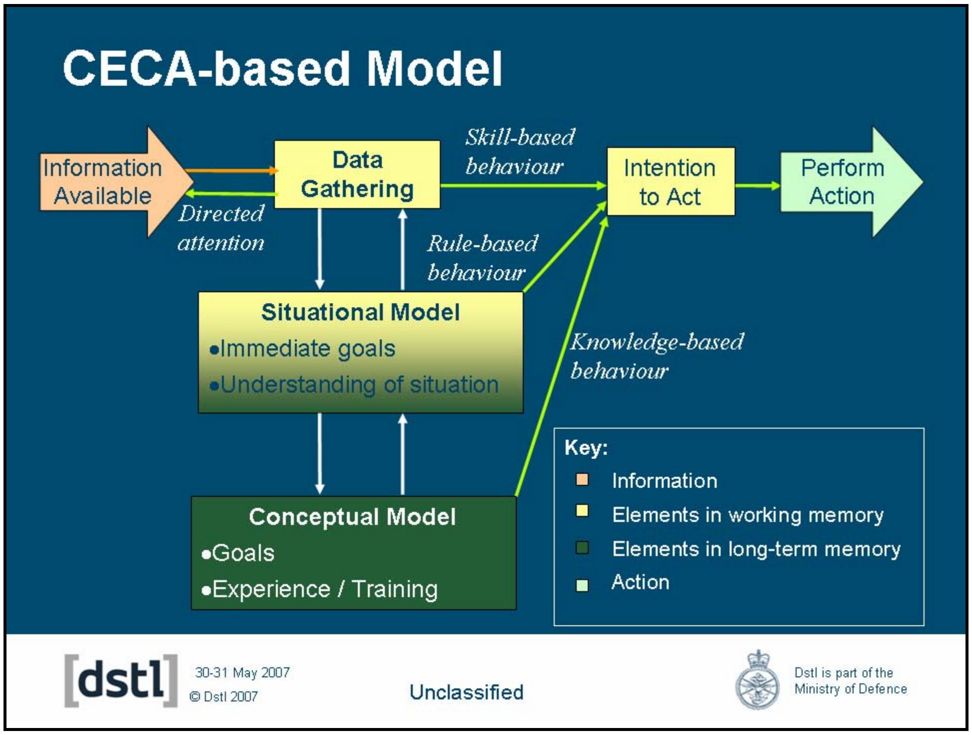
CECA-based Model
Information Available
Data Gathering
Skill-based behaviour
Intention to Act
Perform Action
Directed attention
Rule-based behaviour
Situational Model
•Immediate goals
•Understanding of situation
Knowledge-based behaviour
Key:
Information
Elements in working memory
Elements in long-term memory
Action
Conceptual Model
•Goals
•Experience / Training
[dstl]
30-31 May 2007
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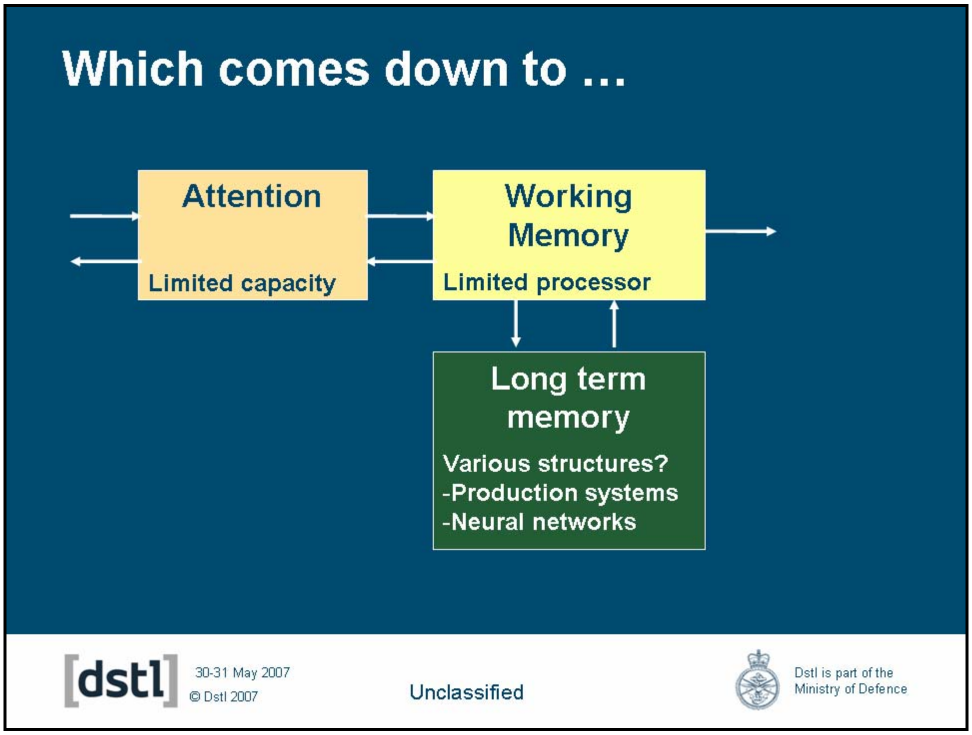
Which comes down to …
Attention
Limited capacity
Working Memory
Limited processor
Long term memory
Various structures?
-Production systems
-Neural networks
[dstl]
30-31 May 2007
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References

- Bryant, D.J., Lichacz, F.M.J., Hollands, J.G. and Baranski, J.V. (2004) ‘Modeling Situation Awareness in an Organizational Context: Military Command and Control’, in Banbury, S. and Tremblay, S. (eds) *A Cognitive Approach to Situation Awareness: Theory and Application*, Ashgate: Aldershot, UK.
- Endsley, M.R. (1995) ‘Toward a Theory of Situation Awareness in Dynamic Systems’, *Human Factors*, vol. 37(1), pp.32-64.
- Klein, G.A. (1993) ‘A Recognition-Primed (RPD) Model of Rapid Decision Making’, in Klein, G.A., Orasanu, J., Calderwood, R. and Zsambok, C.E. (eds) *Decision Making in Action: Models and Methods*, Ablex: Norwood, NJ.
- Rasmussen, J. (1993) ‘Deciding and Doing: Decision Making in Natural Contexts, in Klein et al. (eds), op cit.

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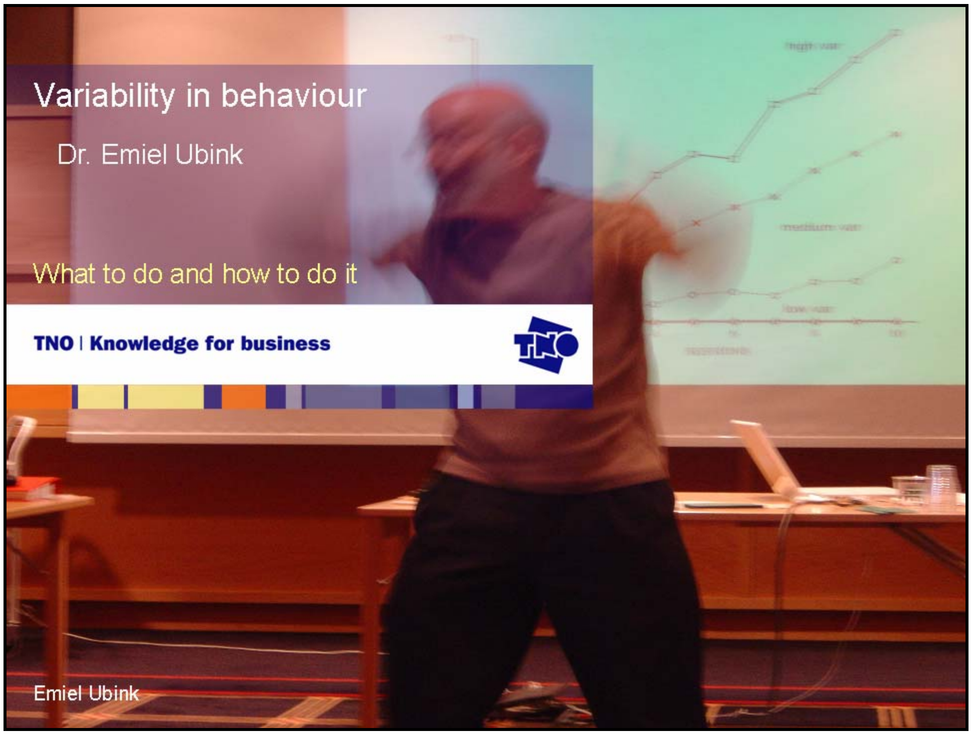


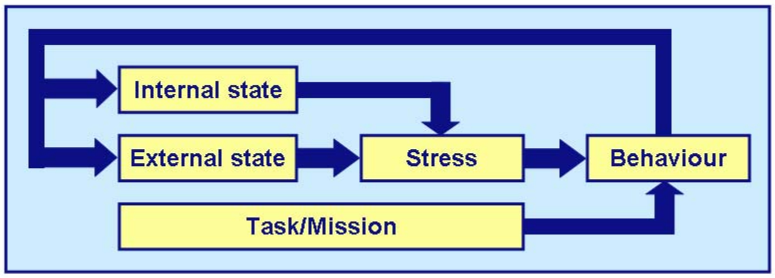
Variability: AI, HF & HBR

- AI: **what** to do (action selection)
- HF: **how** to do it (performance, intensity, ..)
- HBR: 'what' & 'how' are both important and often not separable

2 30 May 2007

Tasks & Stress

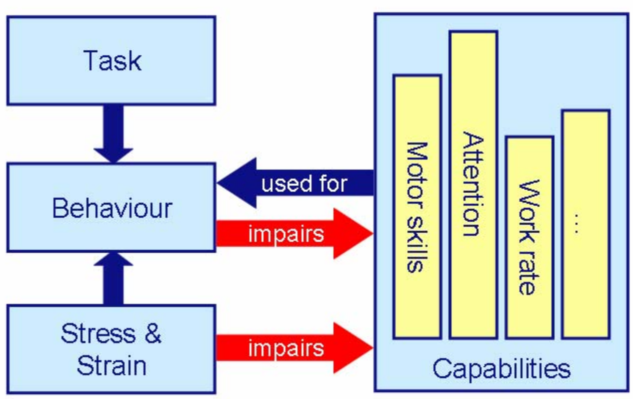
- What & How both depend on relative importance of "stimuli"
  - Tasks → proactive behaviour
  - "Stress" → reactive behaviour



3 30 May 2007

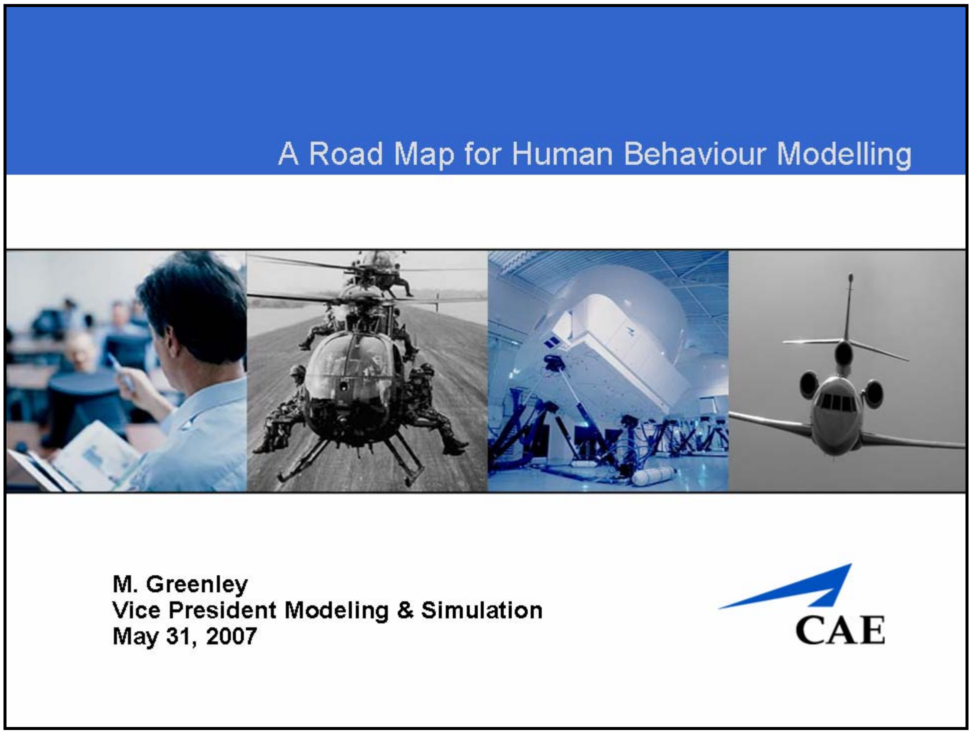
Capabilities

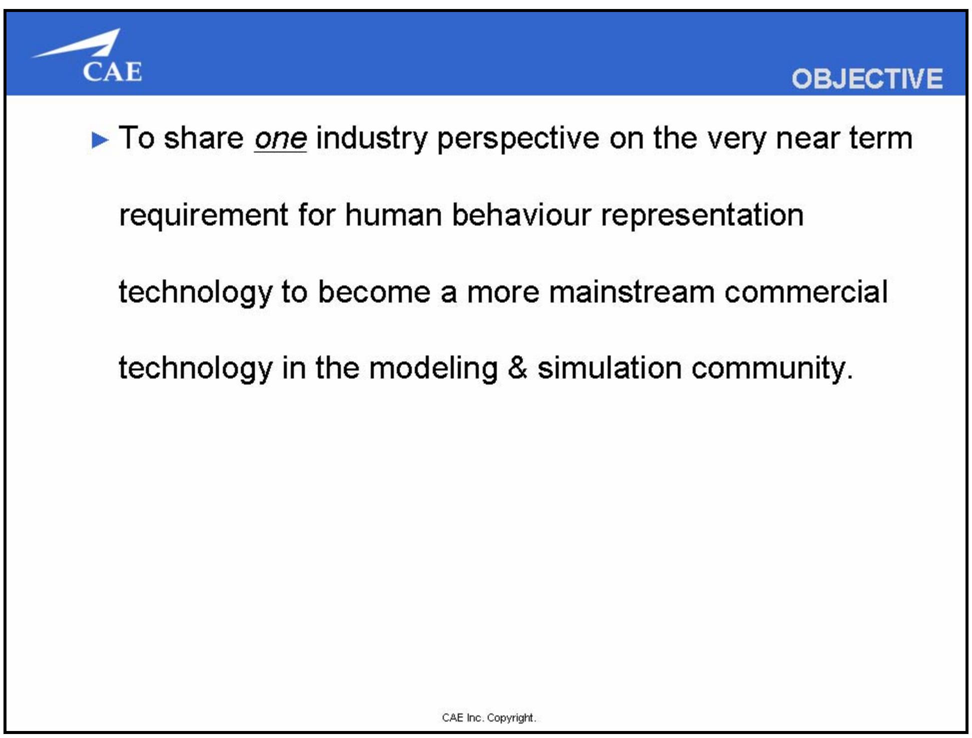
- What & How also depend on availability of resources/capabilities

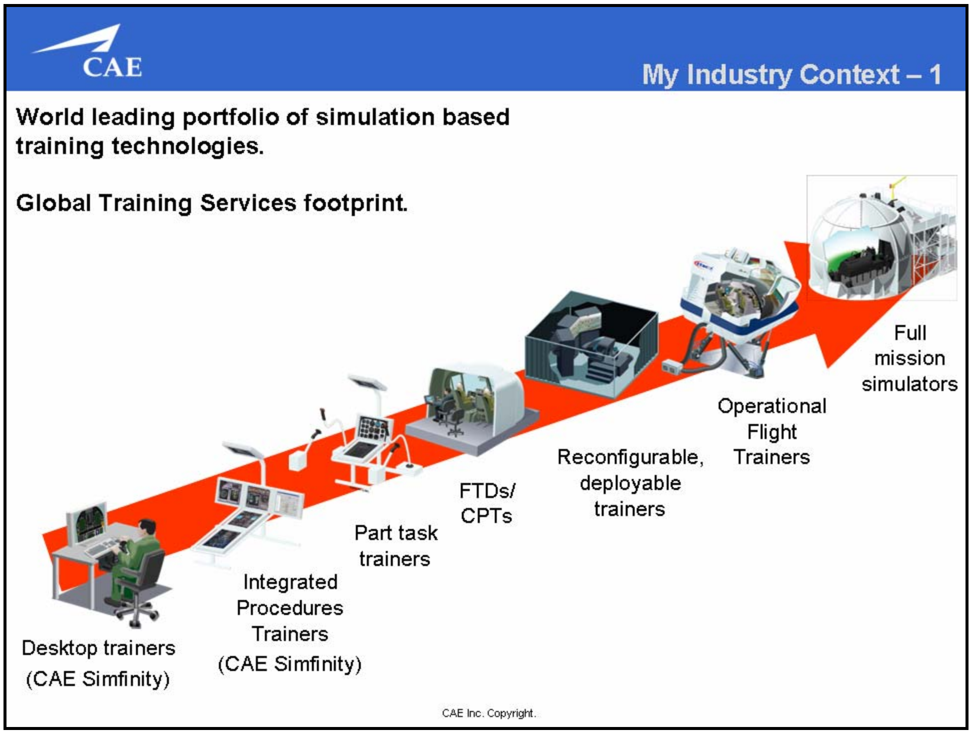


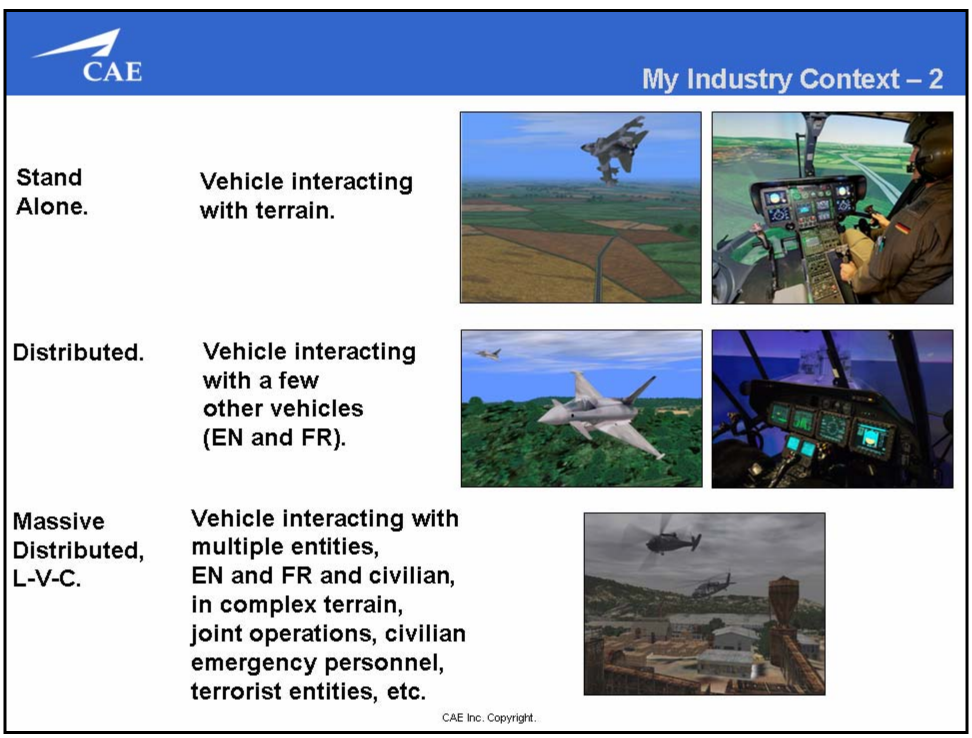
4 30 May 2007

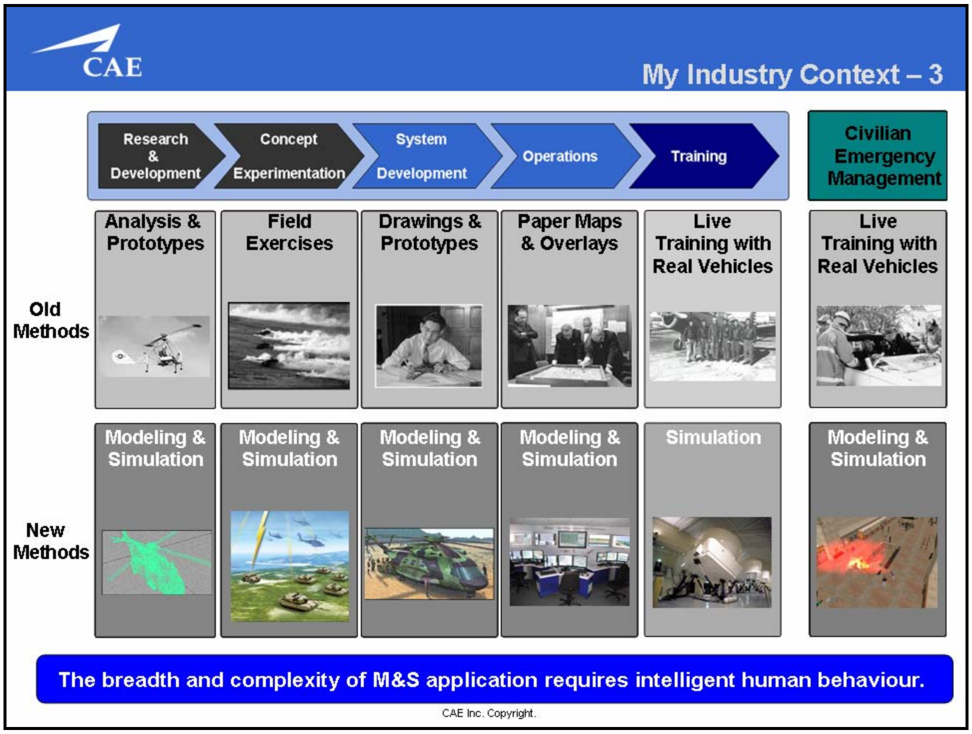
A3.6 KEYNOTE SPEECH – DAY 2

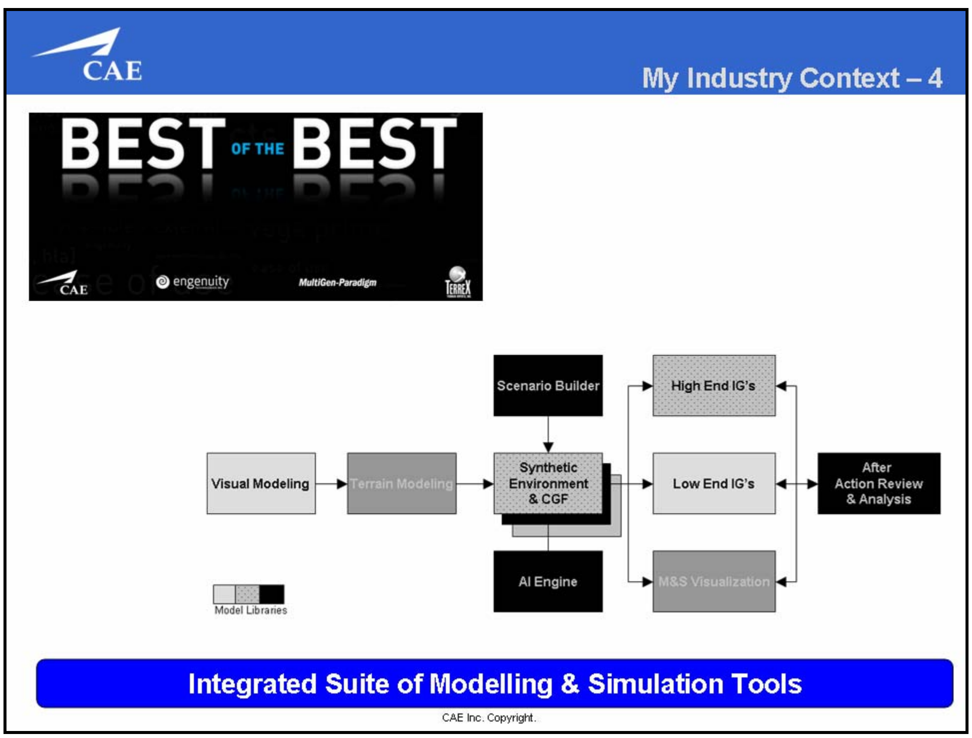


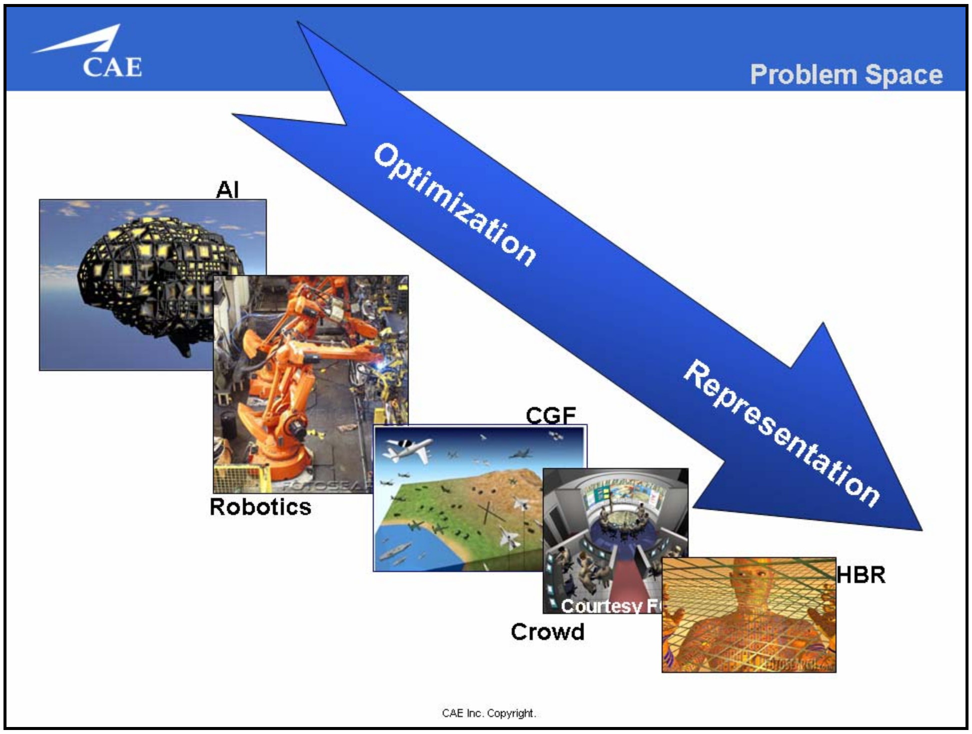


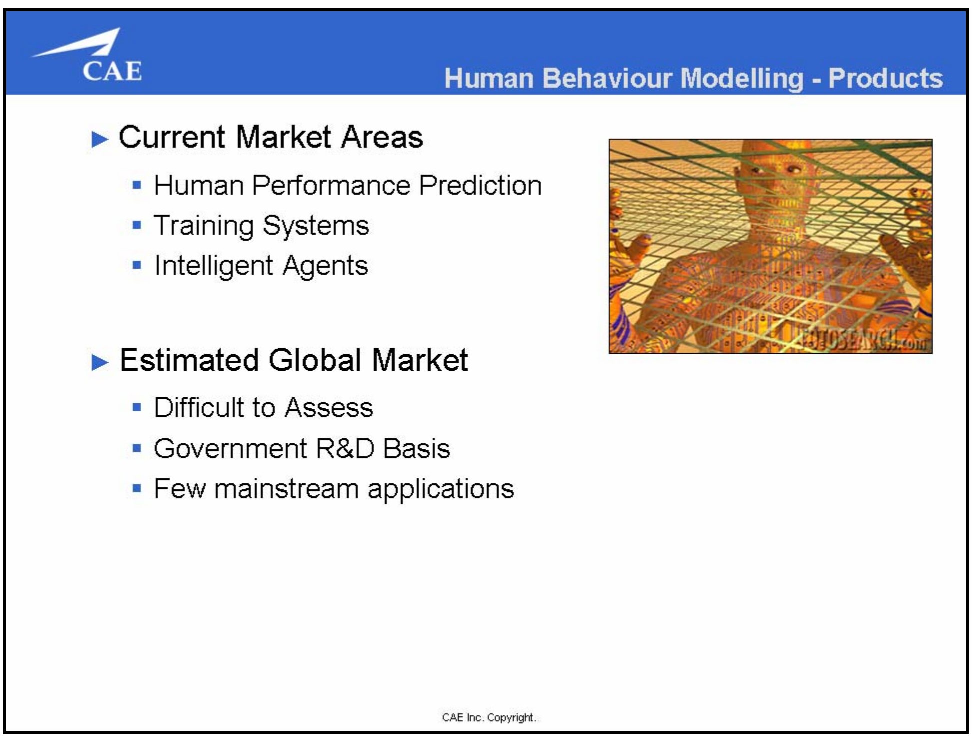

CAE
My Industry Context – 1
World leading portfolio of simulation based training technologies.
Global Training Services footprint.
Desktop trainers (CAE Simfinity)
Integrated Procedures Trainers (CAE Simfinity)
Part task trainers
FTDs/ CPTs
Reconfigurable, deployable trainers
Operational Flight Trainers
Full mission simulators
CAE Inc. Copyright.


CAE
My Industry Context – 2
Stand Alone.
Vehicle interacting with terrain.
Distributed.
Vehicle interacting with a few other vehicles (EN and FR).
Massive Distributed, L-V-C.
Vehicle interacting with multiple entities, EN and FR and civilian, in complex terrain, joint operations, civilian emergency personnel, terrorist entities, etc.
CAE Inc. Copyright.


CAE
My Industry Context – 3
Research & Development
Concept Experimentation
System Development
Operations
Training
Civilian Emergency Management
Old Methods
Analysis & Prototypes
Field Exercises
Drawings & Prototypes
Paper Maps & Overlays
Live Training with Real Vehicles
Live Training with Real Vehicles
New Methods
Modeling & Simulation
Modeling & Simulation
Modeling & Simulation
Modeling & Simulation
Simulation
Modeling & Simulation
The breadth and complexity of M&S application requires intelligent human behaviour.
CAE Inc. Copyright.


CAE
My Industry Context – 4
BEST OF THE BEST
CAE
engenuity
MultiGen-Paradigm
Scenario Builder
High End IG's
Visual Modeling
Terrain Modeling
Synthetic Environment & CGF
Low End IG's
After Action Review & Analysis
AI Engine
M&S Visualization
Model Libraries
Integrated Suite of Modelling & Simulation Tools
CAE Inc. Copyright.

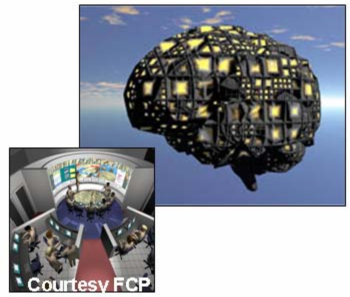

CAE
Problem Space
Optimization
Representation
AI
Robotics
CGF
Crowd
HBR
CAE Inc. Copyright.


CAE
Human Behaviour Modelling - Products
► Current Market Areas
▪ Human Performance Prediction
▪ Training Systems
▪ Intelligent Agents
► Estimated Global Market
▪ Difficult to Assess
▪ Government R&D Basis
▪ Few mainstream applications
CAE Inc. Copyright.

Artificial Intelligence

Current Market Areas

- Dynamic/Intelligent Systems
- Knowledge Management/Decision Aids
- Data Mining
- Interactive Media
- Economic Forecasting
- Environmental Prediction & Analysis
- Expert Systems
- Automated/Autonomous Systems



- Estimated Global Market
  - ~900$ Million USD (US Department of Commerce, 1993)
  - ~11.9$ Billion USD (BCC, 2002)
  - +21$ Billion USD (BCC, 2007)

Robotics

- Current Market Areas
  - Industrial Manufacturing (Automotive, Aerospace, Marine)
  - Autonomous Systems
    - Aerospace and Ground Vehicles
  - Medical Systems
  - Nanotechnology

- Estimated Global Market
  - +16$ Billion USD (BCC, 2007)
  - +24.3$ Billion USD by 2007

CAE

CGFs

- Current Market Areas
  - Military Simulation
  - Emergency Response
  - Civilian Response
  - Infrastructure Analysis (BP)

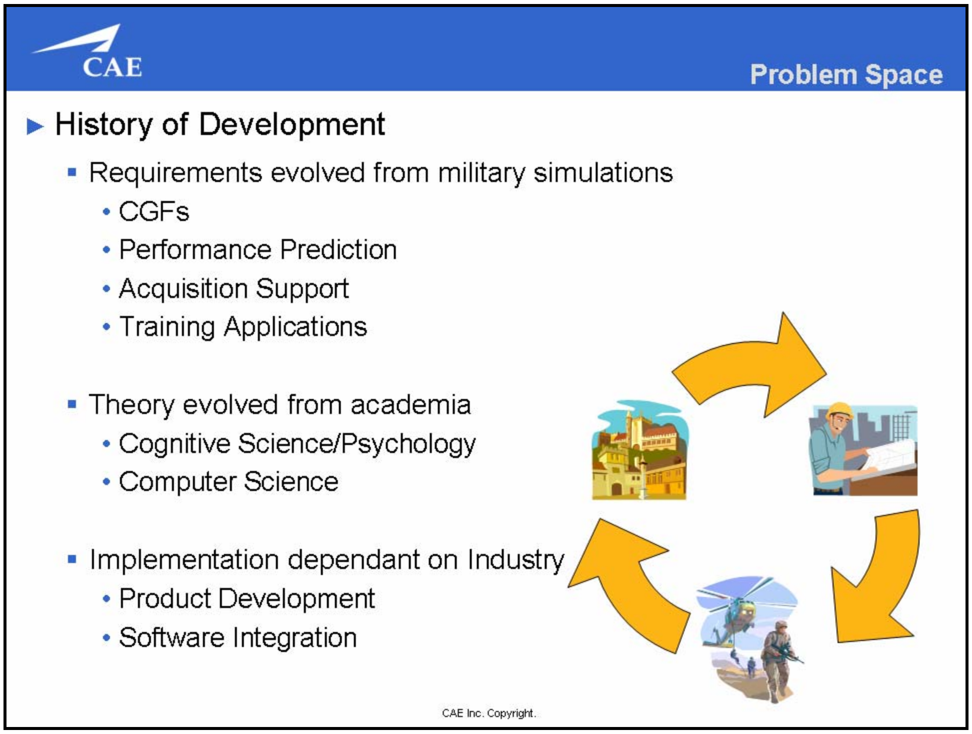
- Estimated Global Market
  - Up to $1B of global activity mixed between a large services market around the application of Government Off the Shelf (GOTS) technologies and a smaller COTS technology demand.

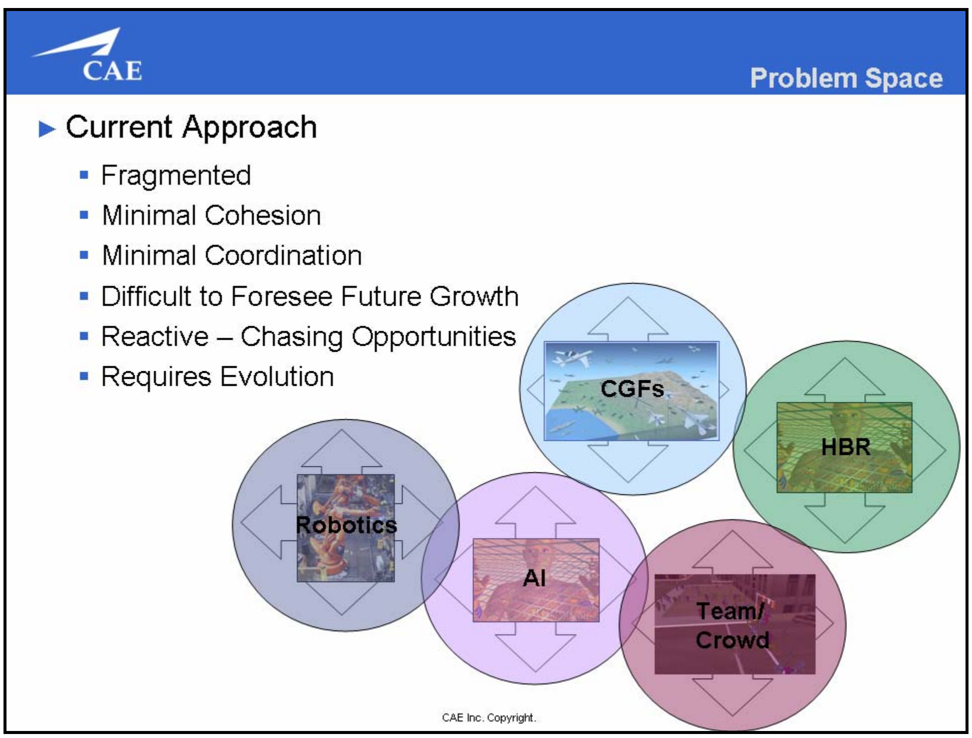
CAE

Crowd Modelling

- Current Market
  - Simulation & Training
  - Games & Entertainment
  - Autonomous System Control
    - UAVs/UGVs
    - Nanotechonology
  - Command & Control

- Estimated Global Market
  - ~3.5$ Million USD in G&E
  - Growing new markets in defense, homeland defense, urban planning, architecture, among others.


CAE
Problem Space
History of Development
Requirements evolved from military simulations
CGFs
Performance Prediction
Acquisition Support
Training Applications
Theory evolved from academia
Cognitive Science/Psychology
Computer Science
Implementation dependant on Industry
Product Development
Software Integration
CAE Inc. Copyright.


CAE
Problem Space
Current Approach
Fragmented
Minimal Cohesion
Minimal Coordination
Difficult to Foresee Future Growth
Reactive – Chasing Opportunities
Requires Evolution
CGFs
HBR
Robotics
AI
Team/
Crowd
CAE Inc. Copyright.

CAE

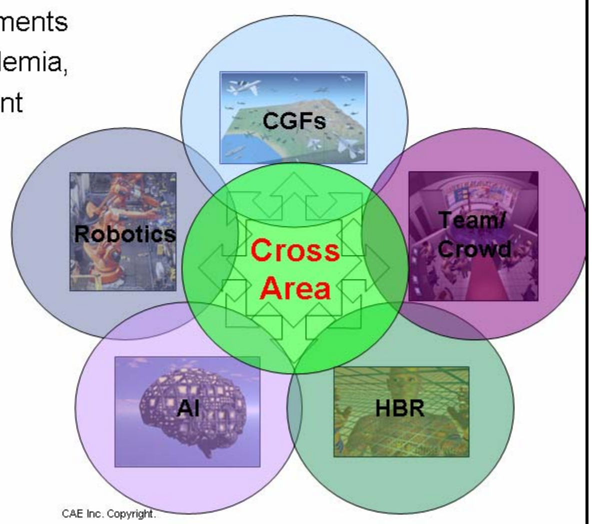
Problem Space

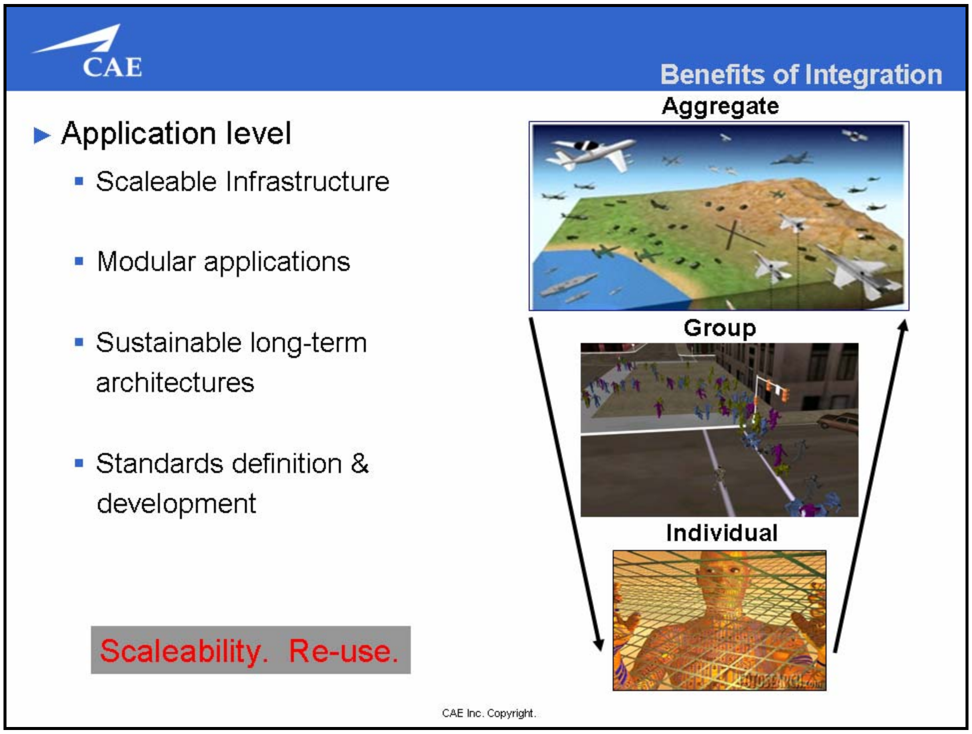
- ► Fragmented Industry
  - Low barriers to entry
    - Many specialized firms
    - Similar to fledgling AI industry in 1980s
  - Highly Specialized Market
    - Niche oriented
    - Independent evolution of technology
    - Multiple toolsets for similar requirements
    - *Dependent on Services for implementation*
  - Lack of Standardization
    - Awareness of requirement
    - Problems for integration

CAE

Future Requirements

- ► Domain Evolution
  - Interaction across areas
  - Define global requirements
  - Defined roles of Academia, Industry & Government




CAE
Benefits of Integration
Application level
Scaleable Infrastructure
Modular applications
Sustainable long-term architectures
Standards definition & development
Scaleability. Re-use.
Aggregate
Group
Individual
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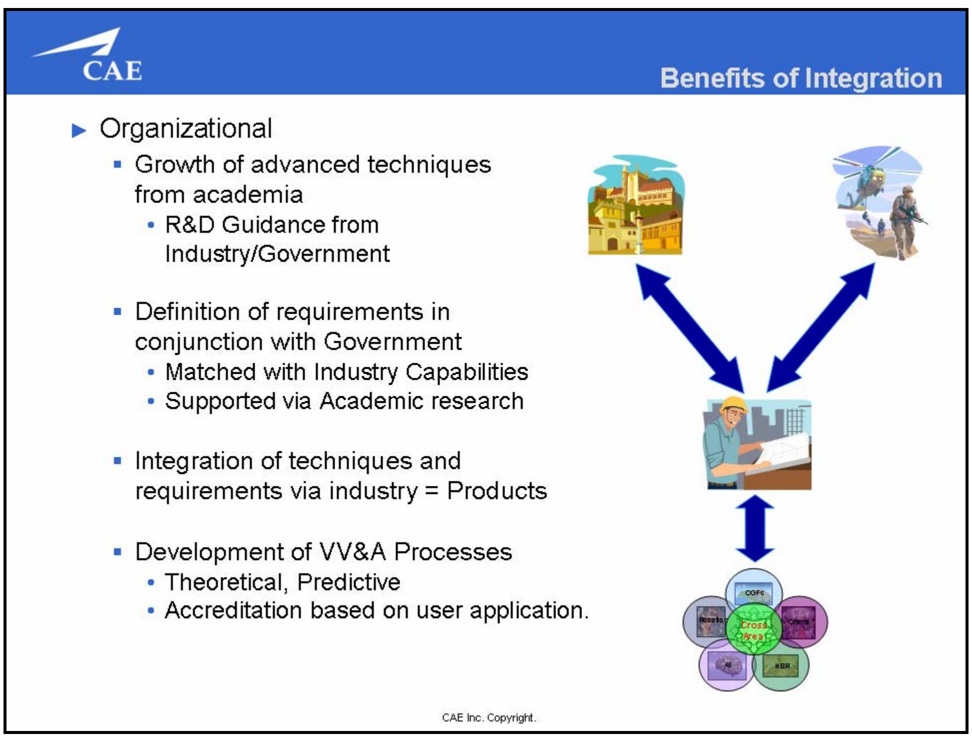
CAE
Benefits of Integration
Organizational
Growth of advanced techniques from academia
R&D Guidance from Industry/Government
Definition of requirements in conjunction with Government
Matched with Industry Capabilities
Supported via Academic research
Integration of techniques and requirements via industry = Products
Development of VV&A Processes
Theoretical, Predictive
Accreditation based on user application.
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Thank You
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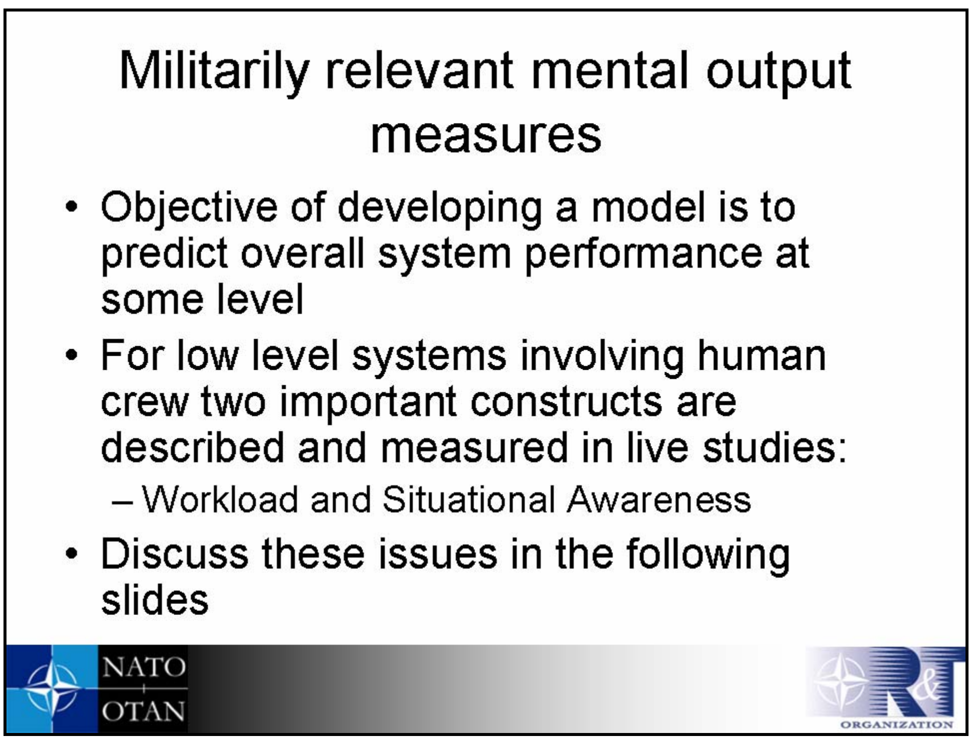
A3.7 MILITARILY RELEVANT MENTAL OUTPUT MEASURES

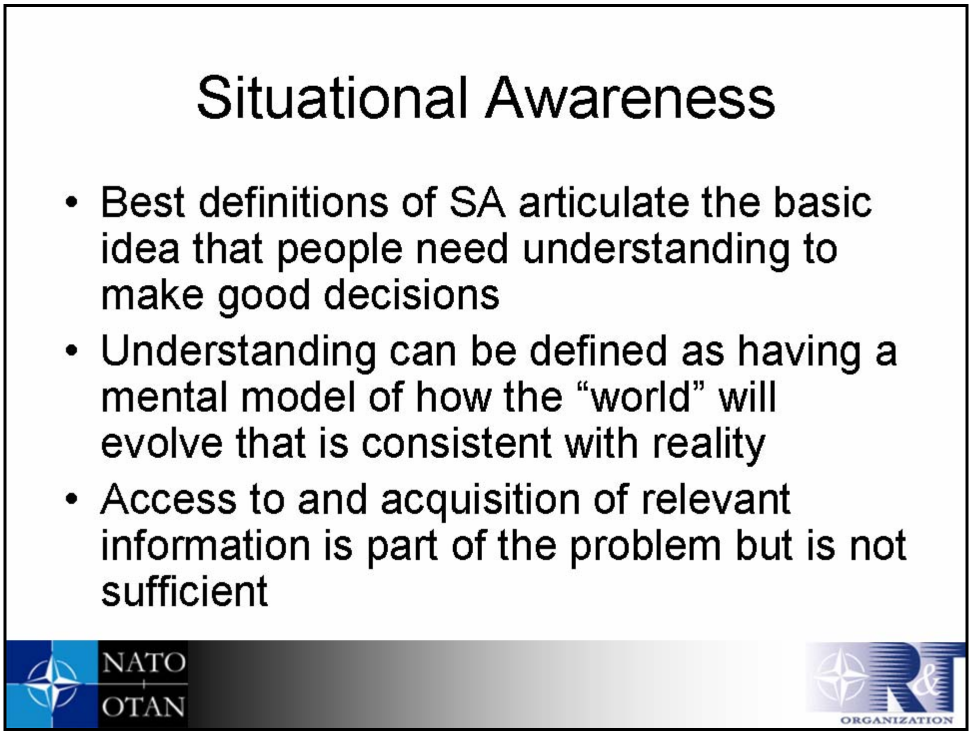


Workload

- A measure of resource demand on the members of the crew
- Important element is time
- Definition of workload involves the idea of rate of resource consumption per unit time
- Less than 100% - fine > 100% problems

Modelling workload

- Many models of workload have been developed
- POP, IP/PCT, POPIP, W/Index, VACP
- POP predicts changes in performance does not address scheduling
- POPIP, IP/PCT models scheduling
- Is a model of workload useful if it does not predict performance/behaviour effects?
- If we can predict performance do we need to predict a measure of workload?


Situational Awareness
• Best definitions of SA articulate the basic idea that people need understanding to make good decisions
• Understanding can be defined as having a mental model of how the “world” will evolve that is consistent with reality
• Access to and acquisition of relevant information is part of the problem but is not sufficient
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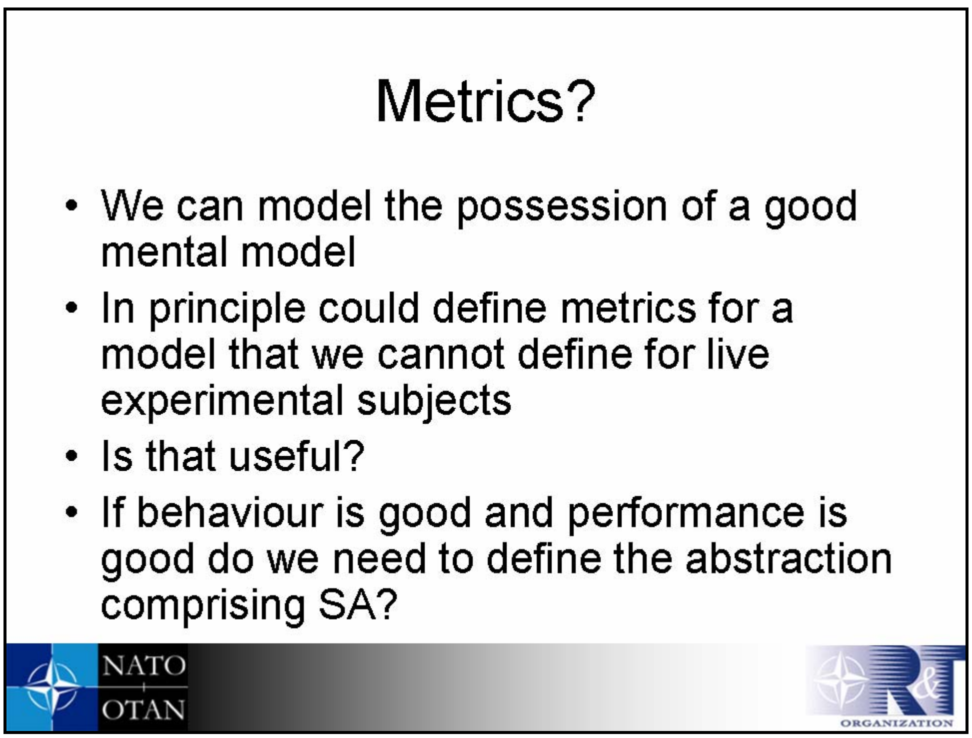
Metrics?
• We can model the possession of a good mental model
• In principle could define metrics for a model that we cannot define for live experimental subjects
• Is that useful?
• If behaviour is good and performance is good do we need to define the abstraction comprising SA?
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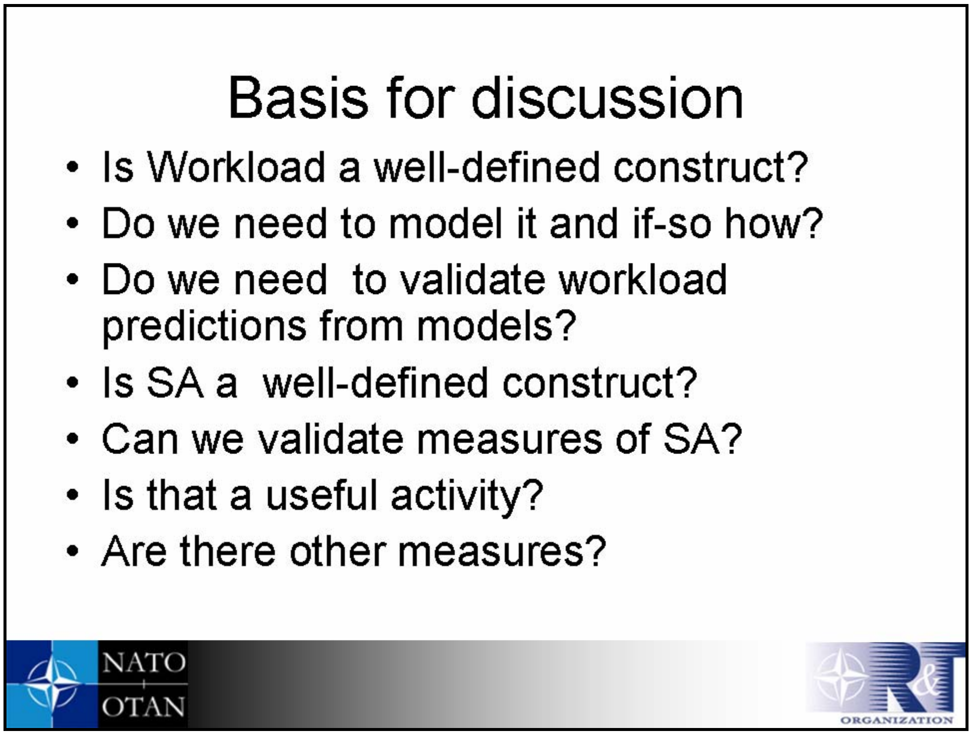
OTAN
ORGANIZATION


Basis for discussion
• Is Workload a well-defined construct?
• Do we need to model it and if-so how?
• Do we need to validate workload predictions from models?
• Is SA a well-defined construct?
• Can we validate measures of SA?
• Is that a useful activity?
• Are there other measures?
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ORGANIZATION

Workload Constructs and Models

Joe Armstrong

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Workload Concepts

- Operator Workload
  - Non-uniform concept (Hart & Staveland, 1988; Xie & Salvendy, 2000)
  - Hypothetical Construct vs Intervening Variable (Gopher & Donchin, 1986)
  - Meta-cognitive
- Multi-Dimensional
  - Task demands vs resources (Wickens, 2002; Young & Stanton, 2002)
  - Dynamic & Static Attributes (North & Riley, 1989; Hendy & Farrell, 1997)
  - Non-attentional parameters (Kahneman, 1973; Meshtaki, 1988)
    - Task environment
    - Moderating variables (e.g. arousal, motivation, emotion)

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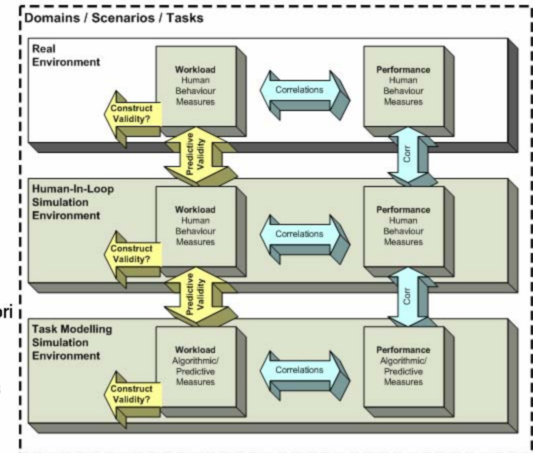
Workload Measurement Techniques

- Categories of Workload Measurement
  - Workload Assessment
    - **Measurement** of dynamic operator workload in complex system
    - Can be applied to
      - Real, Applied Situations
      - Simulated Environments
  - Workload Prediction
    - Development of computational models of workload
    - Used to **Predict** performance a priori
      - Models of Human Behaviour/Cognition
      - Synthesized Environments



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Algorithmic/Predictive Measures

- Applications
  - Diagnostic workload predictions
  - Implemented within Computational Simulations
    - Mathematical/Algorithmic
    - Task Analysis
    - Computer Simulation
- Major Categories
  - Discrete Event Simulations (Task Network Modelling)
  - Cognitive Architectures

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Task Network Modelling

- General Assumptions
  - Human Behaviour Modelled as Interrelated Tasks
  - Performance Values Assigned by Developer
    - Time/Accuracy
    - Task Demands
  - Sequences managed by a discrete event simulator
    - IPME
    - IMPRINT
    - SAINT/MicroSAINT

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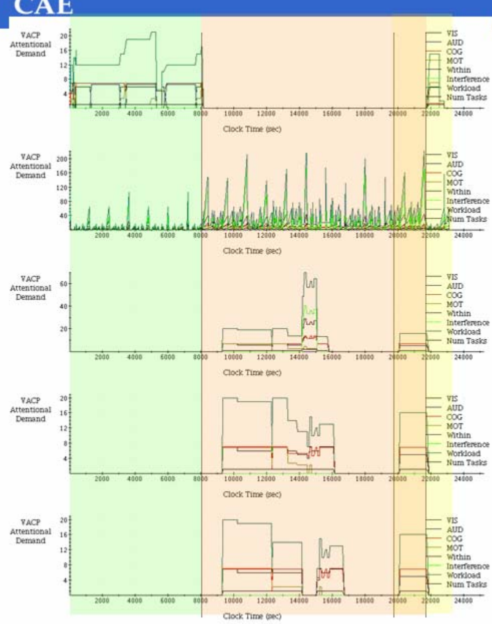
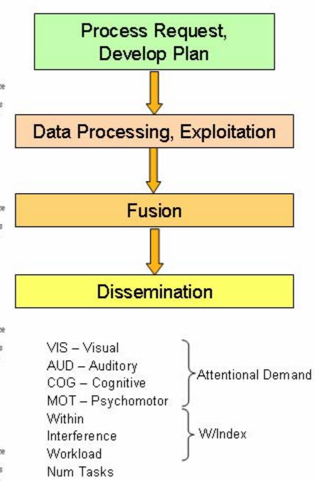


General Model



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Scheduler/Performance Algorithms

- Qualitatively Different than VACP or W/INDEX
  - Measure impact of task demands on task performance
  - Simulates scheduling of tasks based on demand
- Two Major Theories
  - IP/PCT
  - POP & POPIP

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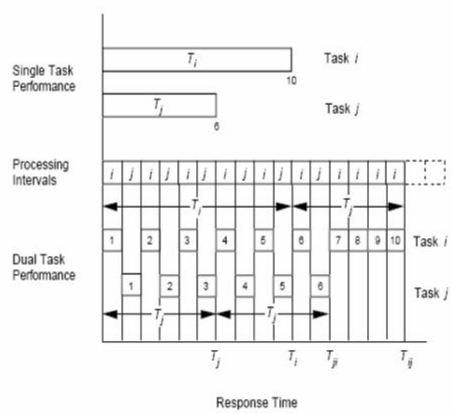
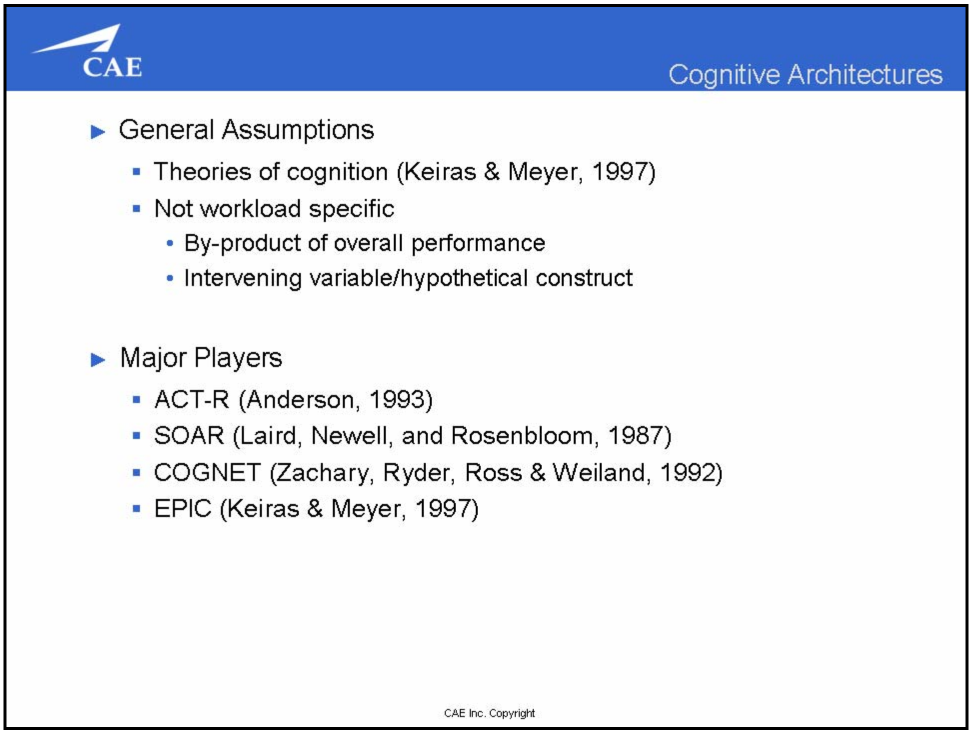
The IP Model



Time-multiplexing in concurrent task processing (Hendy, 2003)


CAE
Cognitive Architectures
General Assumptions
Theories of cognition (Keiras & Meyer, 1997)
Not workload specific
By-product of overall performance
Intervening variable/hypothetical construct
Major Players
ACT-R (Anderson, 1993)
SOAR (Laird, Newell, and Rosenbloom, 1987)
COGNET (Zachary, Ryder, Ross & Weiland, 1992)
EPIC (Keiras & Meyer, 1997)
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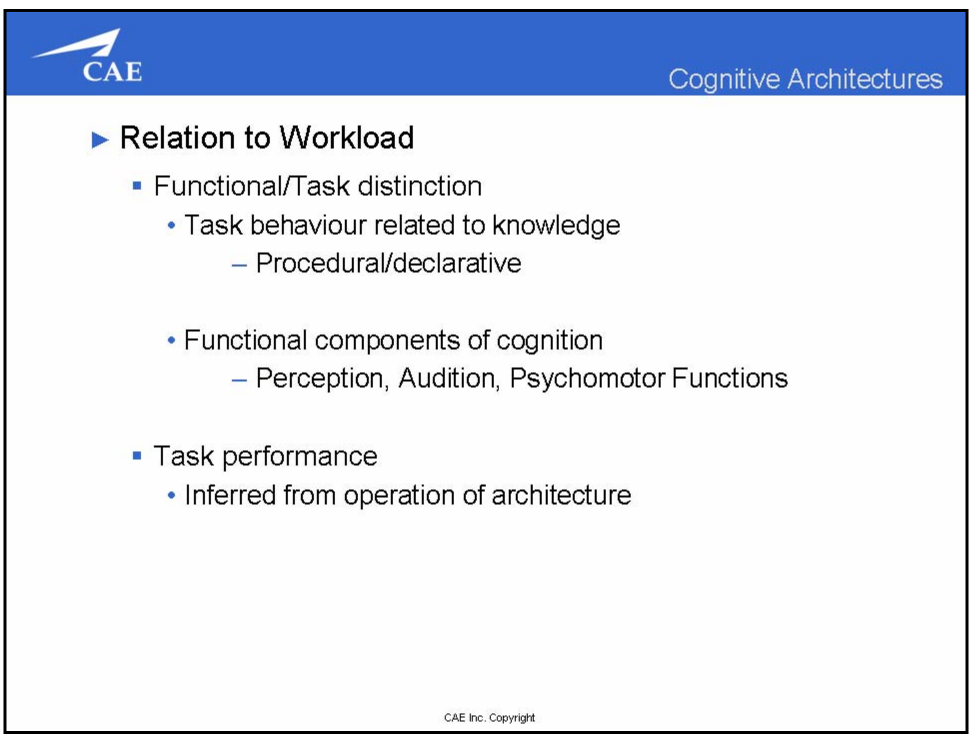
CAE
Cognitive Architectures
Relation to Workload
Functional/Task distinction
Task behaviour related to knowledge
– Procedural/declarative
Functional components of cognition
– Perception, Audition, Psychomotor Functions
Task performance
Inferred from operation of architecture
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Validation Overview

- Contrast of Verification & Validation

Is the model a reflection of the task environment?
(Verification)
Vs

Does the model predict reality?
(Validation)

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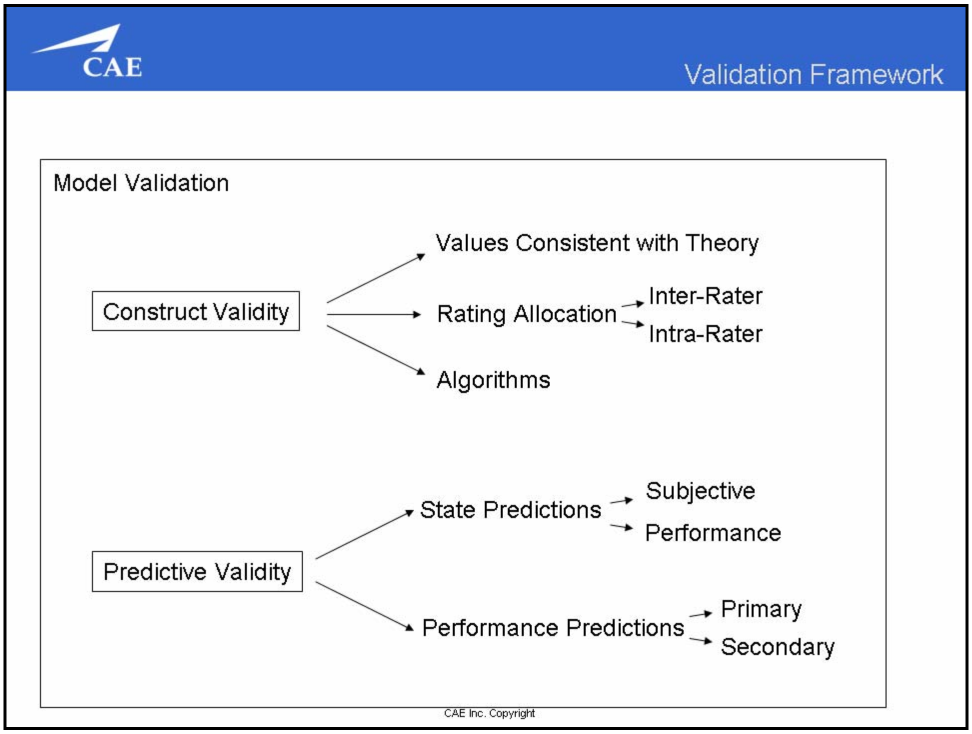
Concepts of Validation

- Criterion
  - Predictive and Concurrent (Cronbach & Meehl, 1955)
  - Task Performance vs Subjective Estimates
- Content
  - Measuring internal constructs (e.g. task performance/resource demand is a measure of workload)
- Construct
  - Computational Model = Workload Construct


CAE
Validation Framework
Model Validation
Construct Validity
Values Consistent with Theory
Rating Allocation
Inter-Rater
Intra-Rater
Algorithms
Predictive Validity
State Predictions
Subjective
Performance
Performance Predictions
Primary
Secondary
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END
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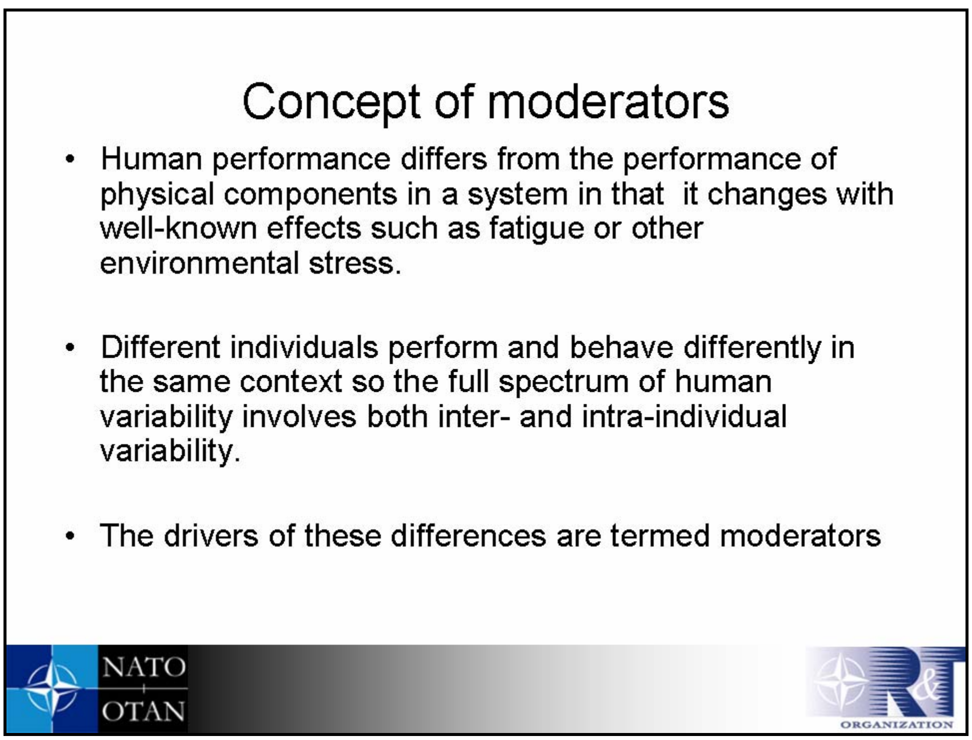
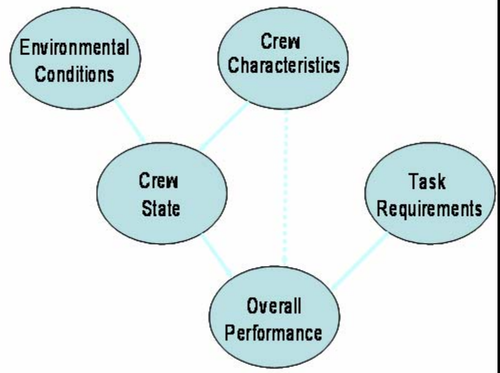
A3.8 THE CONCEPT OF MODERATORS



Classification of moderators

Moderators can be allocated to three groups:
- external moderators (stressors)
- internal moderators (personal attributes)
- collective moderators

Individual stressors



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Key external moderators

- Environmental impact:
  - Sleep loss fatigue/circadian effects and time on task
  - Physical fatigue
  - Thermal effects (thermal strain, dehydration, discomfort)
  - Effects of visual environment
  - Fear, anxiety, morale
  - Task demand — workload

Sample development since 1995

- Development of SAFE by DERA/QinetiQ to model the effects of fatigue, circadian rhythm and time-on-task implemented in IPME
- Development of thermal models that can be coupled to task network models.
- BAE SYSTEMS ORACLE vision model coupled to IPME
- DERA/QinetiQ developed the Prediction of Operator Performance (POP) Workload model – validated in experiments

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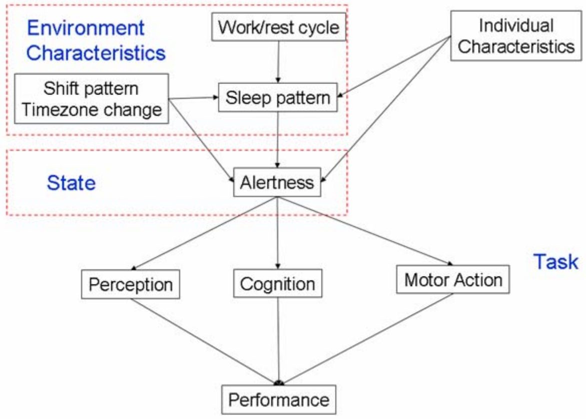
Detailed model of sleep loss



Key internal moderators

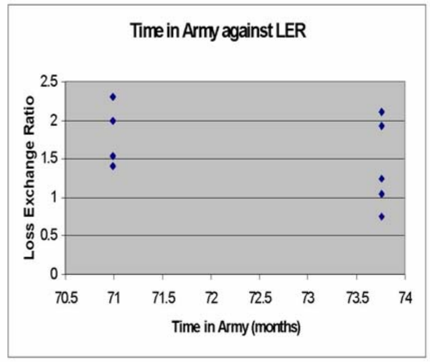
- Personal characteristics
  - Training
  - Experience
  - Personality – including coping style and culture
  - General intelligence

Sample Development since 1995

- Development of the Performance Shaping Function for Experience by QinetiQ
- Development of Performance Shaping Function for the effects of training based on standard results by Micro-Analysis and Design
- Representation of effect of skills in IMPRINT to enable allocation of roles

Key collective moderators

- Collective characteristics
  - Training
  - Experience
  - Ad-hoc team
  - Cohesion
  - Leadership
  - Culture/Organisation



Modelling moderator effects

- Modelling the effects of external moderators is best developed area
- Many stressors have been the subject of detailed research for more than 60 years
- Can build good physiological models and model effects of stressors on state; state to performance and behaviour not as good
- Other areas not as advanced

Problems

- Defining a minimal set of states that affect performance and behaviour is not complete
- The impact of even those states that have been identified is not well-defined
- Behavioural effects are least developed
- A data-limited area

Questions

- For what applications do we need to solve the moderator problem?
- Can we ignore moderators across a range of problems?
- How do we develop valid models if we need to?
- How do we deal with potential moderator interactions?

A word or two about moderators

or a bird in the hand…

Dr. Laurel Allender

The idea

- Take published data
- Derive general degradation factors
- Associated with different task types
- Take modeled tasks
- Denote as task type X (up to 3 task types with weights = 1)
- Apply degradation factor to modeled task
- Run model and compare with non-degraded baseline

PTS

- Personnel characteristics
  - Data collected on 9000 Soldiers, updated w/ longitudinal data
- Training
  - Recently updated
- Stressors
  - Heat + humidity
  - Cold + wind chill
  - Noise
  - Sleeplessness
  - Protective clothing

Task taxonomy

- Fine motor discrete
- Fine motor continuous
- Gross motor light
- Gross motor heavy
- Visual
- Auditory
- Cognitive – decision making…
  - (a la Berliner, see Fleishman)

The general formula *(notional data)*

- Performance moderator effects on tasks as a function of task type
  - e.g., hours since last sleep 20 hours = performance decrease of 5% for cognitive tasks
  - derived from published data
  - % decrease applied to performance estimates attached to cognitive tasks in network model

An existing modeling tool

IMPRINT

Improved Performance Research Integration Tool

- with numerous applications to Army systems

A3.9 COMPLEXITY, HIERARCHY, MODULARITY AND VALIDITY IN HBR ARCHITECTURES

Institute of Cognitive Science

On the Validity of Cognitive Models

Carleton UNIVERSITY
Canada's Capital University

Robert L. West

Institute of Cognitive Science

types of validity

- Face validity
  - Model seems realistic to people who have done the task
- Model validity
  - The model fits the task data (without extensive parameter fitting)
  - Data sets
  - Better ways of fitting
- Predictive validity
  - The model can fit other data from the same task (without major changes)
  - The model makes a novel prediction that can be tested

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types of validity

- Architecture validity
  - Model uses a well researched architecture (with no hidden tricks)
  - Good architecture
    - Many studies showing that it accurately predicts human behavior across a wide variety of tasks
    - Established parameter values
    - Neural correlates
  - Offloads validity onto universities
    - If the architecture is open source
      - E.g., SOAR, EPIC, LIBRA, ACT-R

3

Institute of Cognitive Science

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types of validity

- Agent validity
  - Model is consistent with other models of similar tasks
  - Goal should be to develop agents that have general skills
    - e.g., driving
- Comparative validity
  - Are other models of the same thing similar or different?
  - Is there convergence?
  - If not is there some way to compare competing models
- Publishing
  - Models need to be accessible

4


Institute of Cognitive Science
Thank You
Questions??
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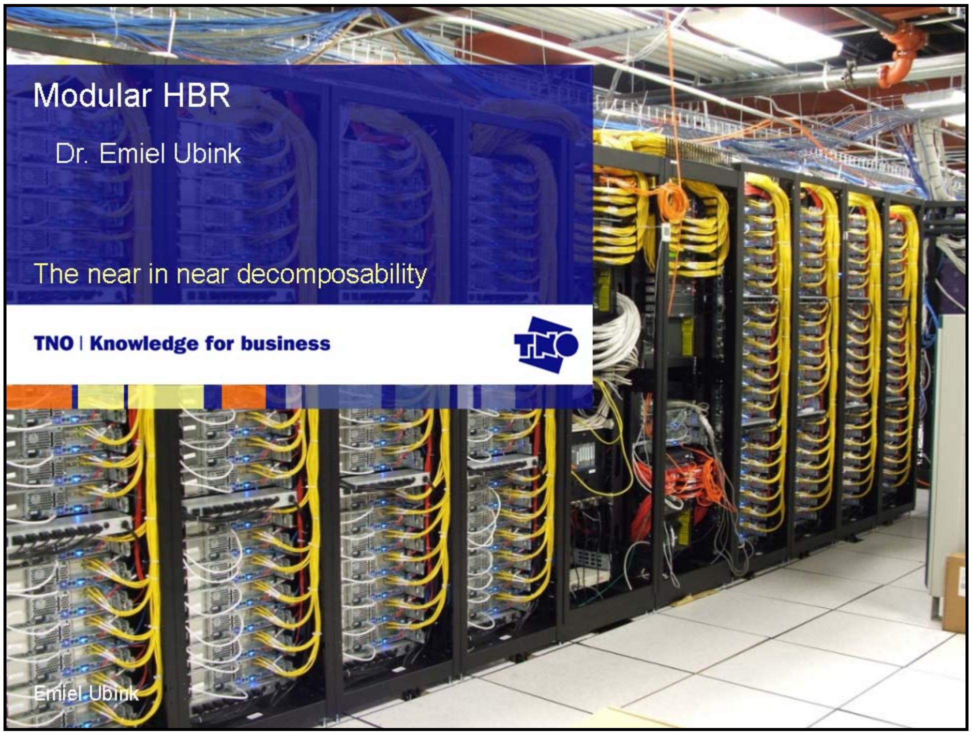
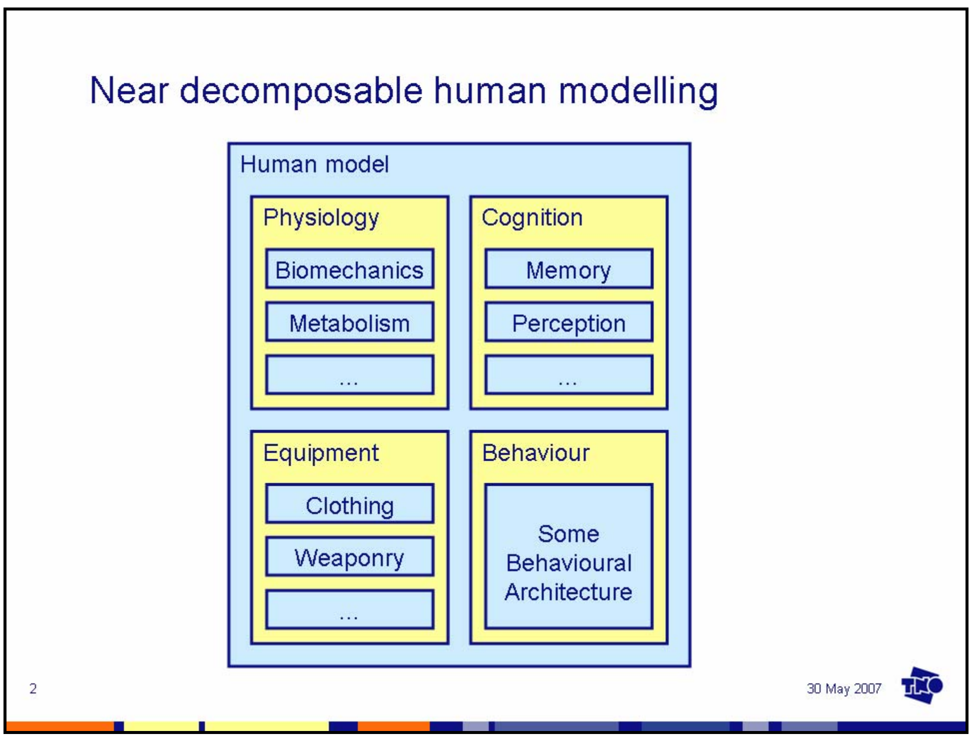
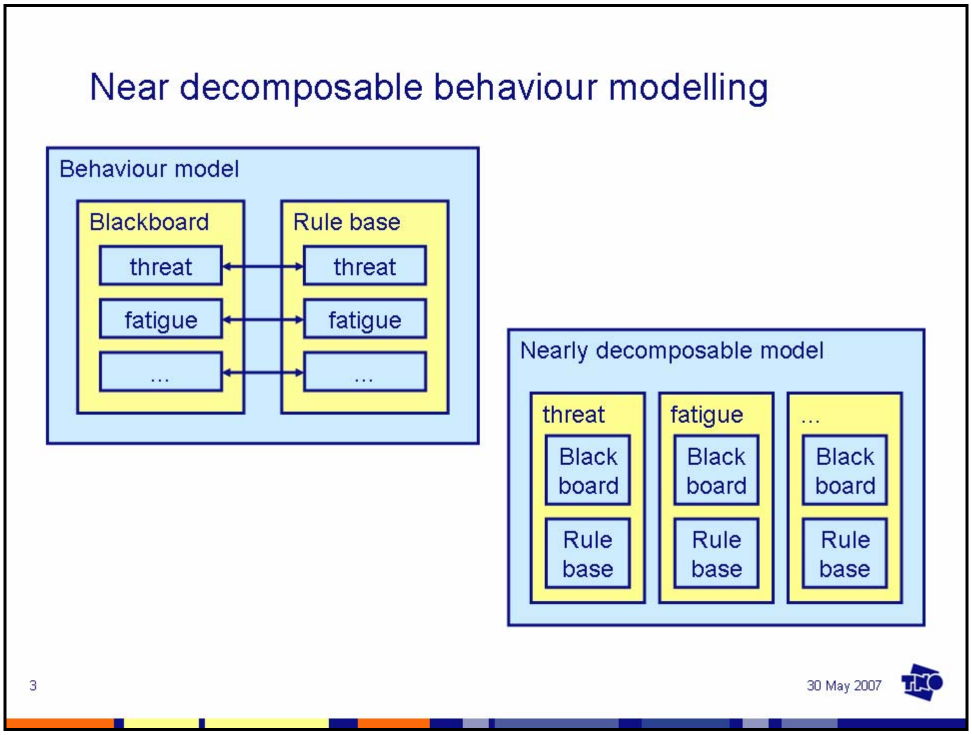
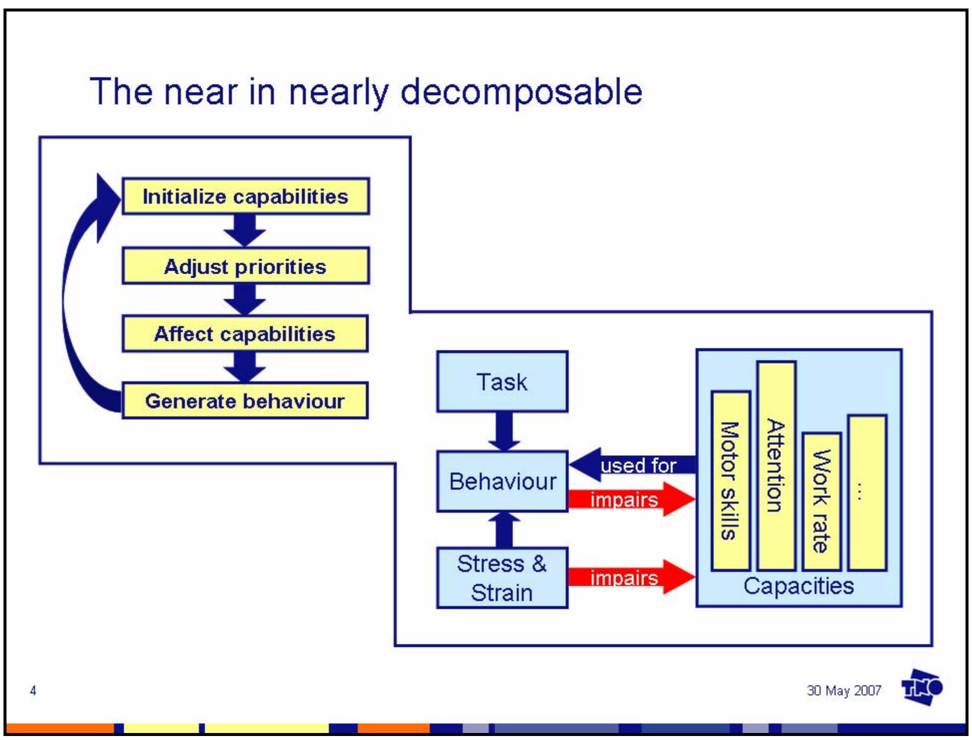
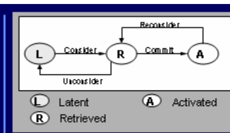

Modular HBR
Dr. Emiel Ubink
The near in near decomposability
TNO | Knowledge for business
Emiel Ubink


Near decomposable human modelling
Human model
Physiology
Biomechanics
Metabolism
...
Cognition
Memory
Perception
...
Equipment
Clothing
Weaponry
...
Behaviour
Some Behavioural Architecture
2
30 May 2007


Near decomposable behaviour modelling
Behaviour model
Blackboard
Rule base
threat
threat
fatigue
fatigue
…
…
Nearly decomposable model
threat
fatigue
…
Black board
Rule base
Black board
Rule base
Black board
Rule base
3
30 May 2007


The near in nearly decomposable
Initialize capabilities
Adjust priorities
Affect capabilities
Generate behaviour
Task
Behaviour
Stress & Strain
used for
impairs
impairs
Motor skills
Attention
Work rate
…
Capacities
4
30 May 2007



Comparative Analysis of Frameworks for Knowledge-Intensive Intelligent Agents

Randolph M. Jones

Robert E. Wray

30-31 May 2007

NATO Specialists Meeting HFM-143/RSM On
Human Behaviour Representation in Constructive Modeling

Motivations

- Software engineering principles have been applied mostly to "light" agent architectures
- Cognitive and agent architectures share more with each other than commonly recognized
  - How can we evaluate until we can compare?
  - We need a common language for intermediate components
- Better reuse would benefit applications development as well as science
  - Easier to build new models and new architectures
  - Easier to integrate models into applications
  - Easier to communicate success to broader communities

Knowledge-Rich Intelligent Agents

- Significant encodings of knowledge
  - Contrast with "Light" agents: limited, restricted capabilities
  - Intended to perform the role of one or more humans
- Integrated with non-trivial environments
  - Dynamic, unpredictable, inaccessible, continuous
  - Often require real-time response
- Situation interpretation/representation a essential part of decision making
- Long-lived ("enduring") in many dimensions
  - Execution time
  - Software life cycle

Goals for Architectures for Intelligent Behavior

- Comprehensive
  - Explicit support of common architectural processes and representations
- Scalable
  - Engineered for efficiency and composability
  - Designed around abstract component interfaces
- Stable
  - Well-defined abstract component types
  - Well-engineered implementation
- Easy to use
  - Extensible
  - Integrated design with high-level formal abstractions (languages, libraries, tools)

Assessing the State of the Art

- No (existing) architecture supports *all* basic representations & processes needed for most applications
- Large gap between notional architecture components and software implementation
  - Few intermediate, reusable structures and components
- Not engineered for real-world applications
  - Robustness, ease-of-use, scalability, stability

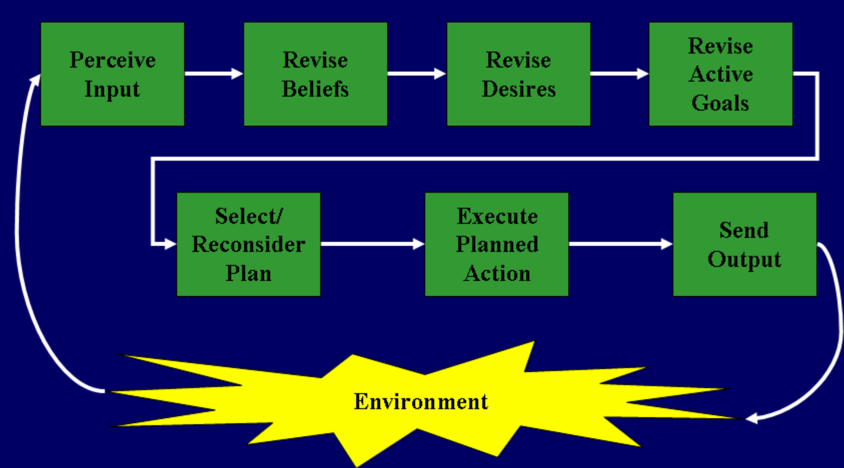
Incomplete Support for Basic Representations

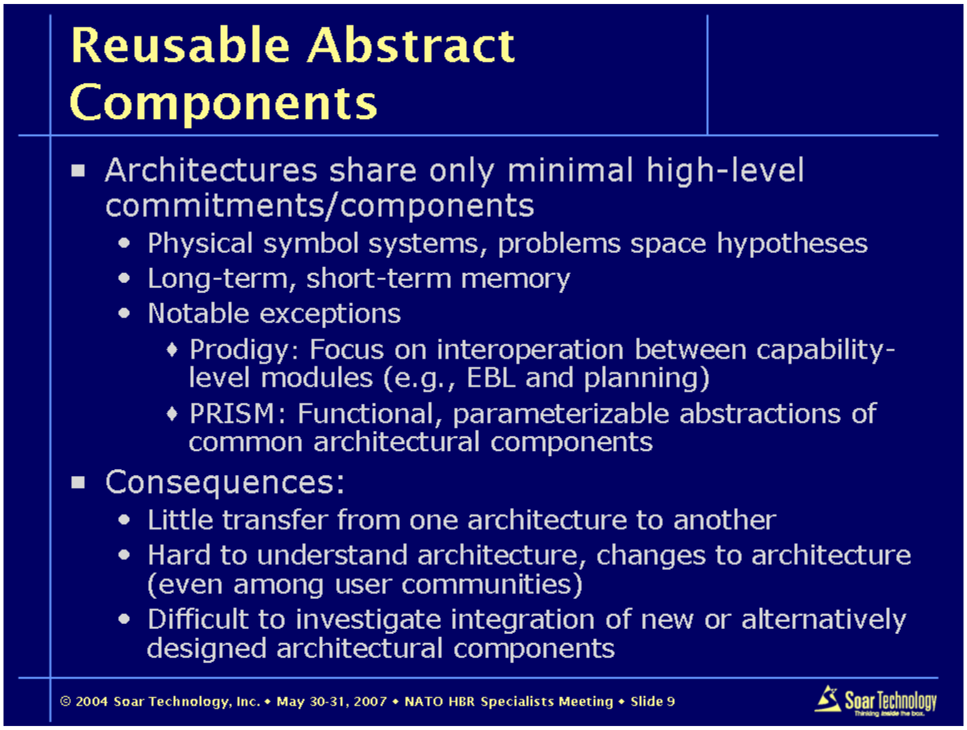
- Examples of missing representations & functionality
  - Initial analysis: BDI, GOMS, Soar
  - Analytical framework inspired in part by BDI (Beliefs, Desires, Intentions, Commitment, Reconsideration)
- Consequences:
  - Labor intensive, ad hoc design & development
    - Where the architectures lack representational or processing power, users must "program" solutions to gaps
    - Exacerbates "tangling" between domain knowledge representations & gap-driven solutions
  - Minimal knowledge reuse
    - Ad hoc development not applicable in new task environments

Comparative Framework

- Representational elements
  - Inputs, Justified Beliefs, Assumptions, Desires, Active Goals, Plans, Actions, Outputs
  - Superset of GOMS, Soar, BDI representations; not an exhaustive list
- Design dimensions
  - Representation formalism
    - How is each type of element represented?
  - Commitment strategy
    - Under what conditions does each type of element get selected/activated/instantiated?
  - Reconsideration strategy
    - Under what conditions does each type of element get removed/deactivated/released?

Abstract Knowledge Cycle




Reusable Abstract Components
Architectures share only minimal high-level commitments/components
Physical symbol systems, problems space hypotheses
Long-term, short-term memory
Notable exceptions
Prodigy: Focus on interoperation between capability-level modules (e.g., EBL and planning)
PRISM: Functional, parameterizable abstractions of common architectural components
Consequences:
Little transfer from one architecture to another
Hard to understand architecture, changes to architecture (even among user communities)
Difficult to investigate integration of new or alternatively designed architectural components
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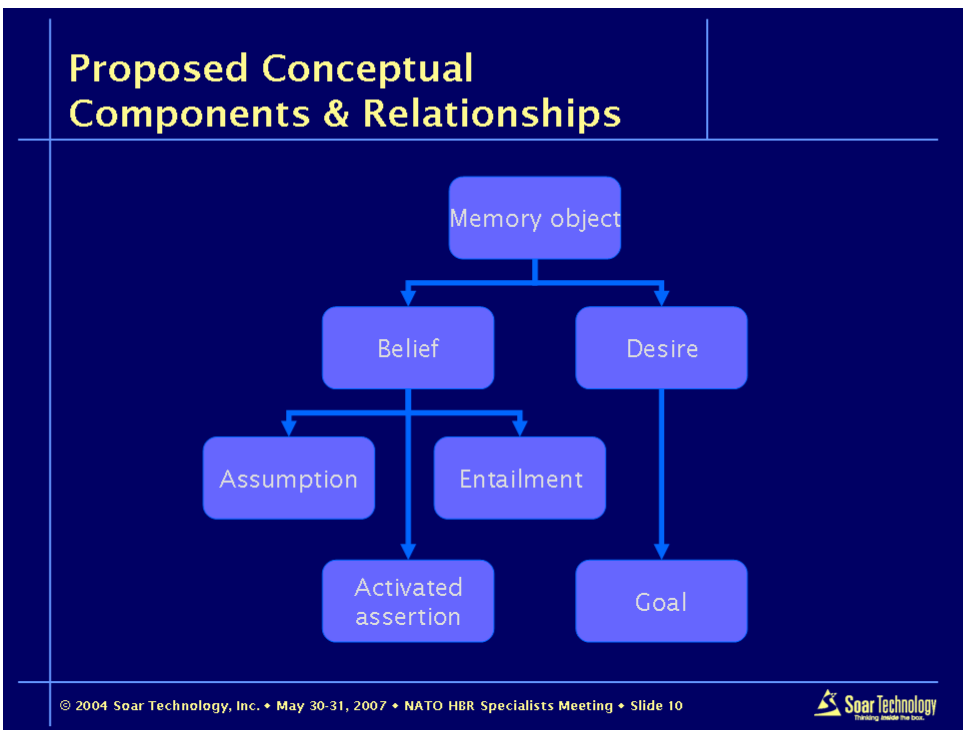
Proposed Conceptual Components & Relationships
Memory object
Belief
Desire
Assumption
Entailment
Activated assertion
Goal
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Proposed Conceptual Components & Relationships

Commit: Persistent assertion
Assumption
Recon: Persistent assertion

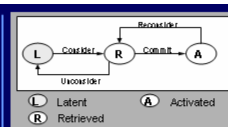
Commit: Truth maintenance
Entailment
Recon: Truth maintenance

Commit: Activation threshold
Activated Assertion
Recon: Activation threshold

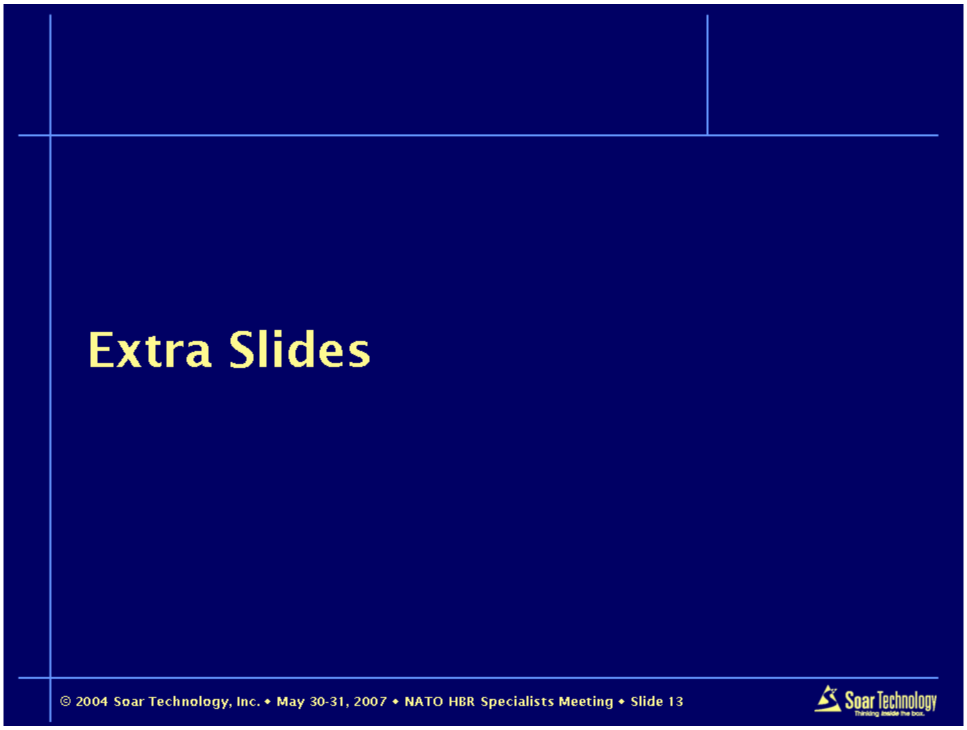
Commit: Persistent assertion
Context-Sensitive Assumption
Recon: Persistent assertion
Recon: Truth Maintenance

Commit: Persistent assertion
Temporal Assumption
Recon: Decay function

Summary



- Intelligent agent architectures are complex software systems and require:
  - Comprehensive support for necessary knowledge representations
  - Composable, well-defined software components
  - Design that addresses understandability and usability challenges from the outset
- Long-term strategy
  - An abstract machine based on common functional components (e.g., commitment, beliefs)
  - Interoperable object libraries as instantiations of abstract components (e.g., preference-mediated deliberation, FOPC sentences)
  - Formal framework to provide a bridge between science and implementation
  - Ability to compose components quickly into the "best" architecture for a given task


Extra Slides
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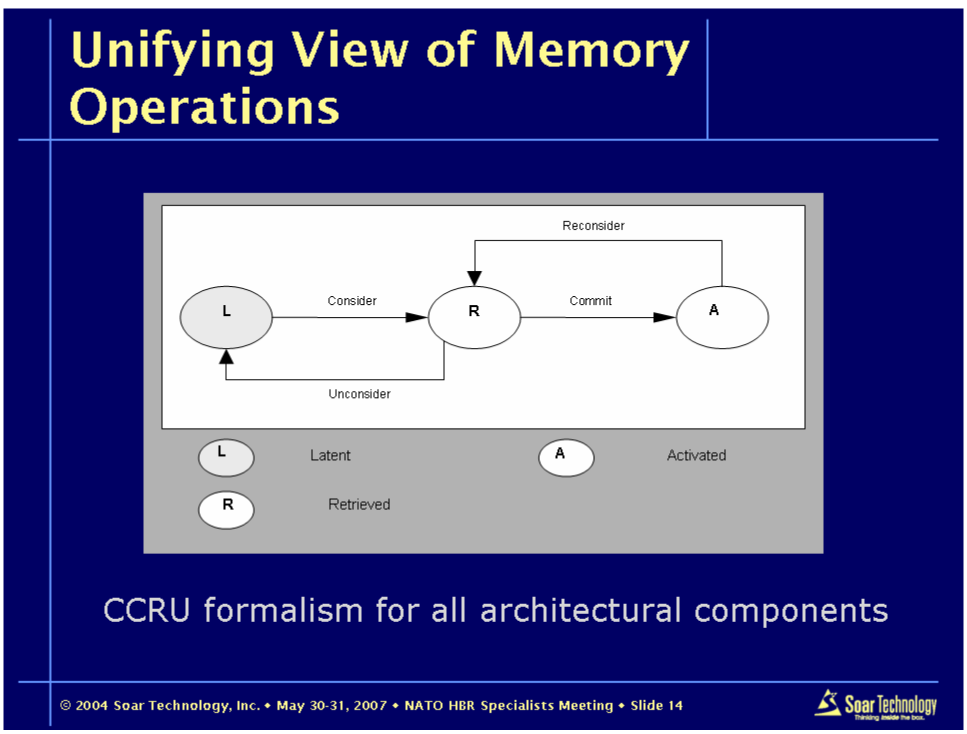
Unifying View of Memory Operations
Reconsider
L
Consider
R
Commit
A
Unconsider
L
Latent
A
Activated
R
Retrieved
CCRU formalism for all architectural components
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Review of Selected Agent Frameworks

- BDI
  - Inspired by formal logic/philosophy
  - Formal sense of rationality
  - Focus on logical consistency between beliefs and goals
- GOMS
  - Inspired by psychology
  - Explicit hierarchical task decomposition
  - Explicit pairing of goals with plans
- Soar
  - Inspired by functionality and philosophy
  - Problem-space hypothesis
  - Physical symbol systems hypothesis
  - Focus on minimal but sufficient set of principles

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Comparisons

Explicitly supported
Partially supported

Base-level Representation		Representation Language	Mechanism of Commitment	Mechanism of Reconsideration
Inputs	BDI	Input Language		
	GOMS	Input Language		
	Soar	Working memory		
Justified Beliefs	BDI	Beliefs	Logical Inference	Belief revision
	GOMS	Working memory	Match-based assertion	
	Soar	Working memory	Match-based assertion	Reason maintenance
Assumptions	BDI	Beliefs	Plan language	Plan language
	GOMS	Working memory	Operators	Operators
	Soar	Working memory	Deliberation/ operators	Operators
Desires	BDI	Desires	Logic	Logic
	GOMS			
	Soar	Proposed operators	Preferences	Preferences

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Comparisons

Explicitly supported
Partially supported

Base-level Representation		Representation Language	Mechanism of Commitment	Mechanism of Reconsideration
Active Goals	BDI	Intentions	Deliberation	Soundness/Decision Theory
	GOMS	Goals	Operators	
	Soar	Beliefs/Impasses	Deliberation	Reason maintenance
Plans	BDI	Plans	Plan selections	Soundness
	GOMS	Methods	Selection	
	Soar			Interleaving
Actions	BDI	Plan language	Atomic actions	
	GOMS	Operators	Operators	
	Soar	Primitive operators	Deliberation	Reason maintenance
Outputs	BDI			
	GOMS	Plan language	Plan language	
	Soar	Working memory	Conditional operators (decoding)	

Reference:

- Jones and Wray (2006) Comparative analysis of frameworks for knowledge-intensive agents. AI Magazine

A3.10 FROM INDIVIDUAL TO GROUP BEHAVIOUR

Topic 7
From individual to group behaviour

Brad Cain

Military simulation:
The early days

Lanchester models

$dx/dt + ky = 0$

$dy/dt + mx = 0$

Attrition models of Force-on-Force

Little in the way of “Human Factors”

Human elements are aggregated in the various coefficients

Small teams

- Representation
  - Single “team” entity
  - Collection of cooperating individuals
- Individual HF aspects may still be relevant
  - fatigue, thermal, etc.
- Each approach has pros/cons
  - entity: conceptually simpler but harder to validate
  - individuals: shared understanding & comms but more detailed models required to represent interactions

NATO
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Additional team attributes

- Additional social elements
  - communication, feedback
  - mutual support, monitoring, task sharing
  - morale, commitment

NATO
OTAN

Large teams and organizations

- Social elements apply to organizations
  - Human Factors modelling requirements
    - goals, procedures, errors, social elements
    - business process models
    - elaborate Lanchester models?
  - Are there HBR requirements in organizational models?
    - perception, reasoning, performance
    - fatigue, thermal

Team models (and organizations?)

- Can we define those essential attributes of teams that require formal models that would make team entity modelling viable?
  - Are validated formal models available?
- Can we model teams of individuals at sufficient resolution and validate them for use in military simulations?
  - What can make this process affordable?
- Can we define the pros and cons of each approach sufficiently so that the military M&S community can make an informed decision about which is the more appropriate in a given context?
- How is an organization representation different from a small team?
  - Do we need to represent explicit EBO behaviours or is it sufficient to represent their “effects”?


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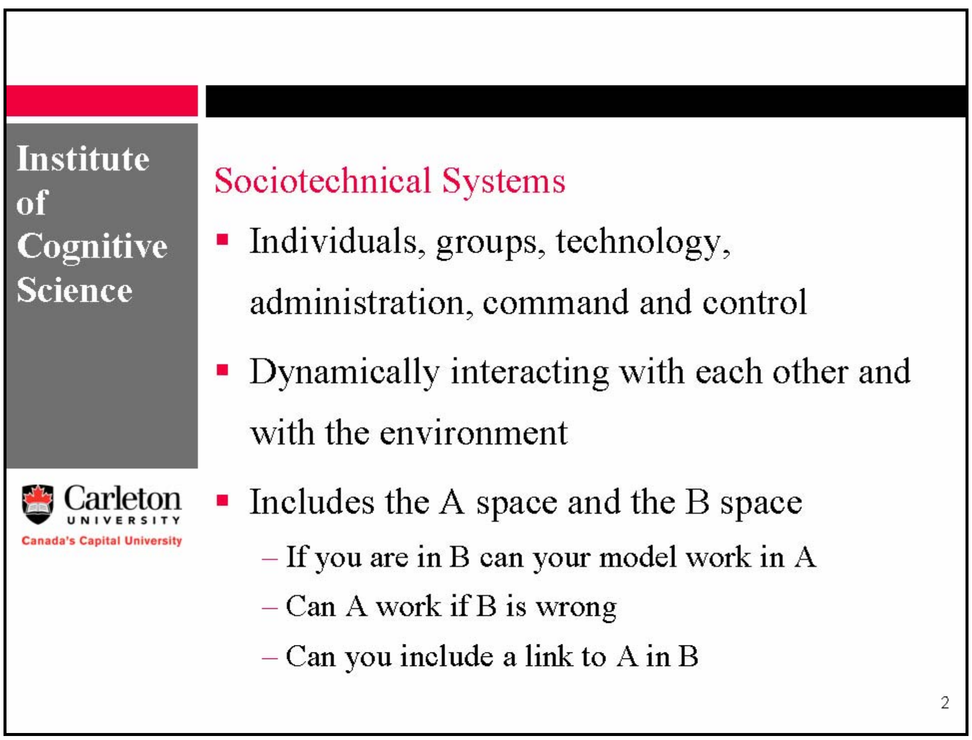
Modelling in Sociotechnical Systems
Carleton UNIVERSITY
Canada's Capital University
Robert L. West
Gabriella Nagy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Sociotechnical Systems
Individuals, groups, technology, administration, command and control
Dynamically interacting with each other and with the environment
Includes the A space and the B space
– If you are in B can your model work in A
– Can A work if B is wrong
– Can you include a link to A in B
2

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GOMS

- Card, Moran, & Newell
- Goals, operators, methods, selection rules
- Very representative of the type of model generally used for military simulations
- GOMS models applied to multi-agent sociotechnical systems
  - West & Yeun
  - Kieras & Santoro
- GOMS does not work well!!!!

3

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Hierarchical goal based systems

- These do not work in sociotechnical system because of:
  - Frequent interruptions
  - Frequent opportunistic task switching
- Therefore, models of individual behavior built in this way will not reflect real behavior in sociotechnical systems
- Can this be fixed?????

4

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SGOMS

- Sociotechnical GOMS
  - Augmented GOMS to cope with
    - Interruptions
    - Task switching
  - Not GOMS specific
    - Will work with any hierarchical goal based system

5

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SGOMS

- Unit tasks - cognitive level
  - GOMS - prevents overload and downtime
  - SGOMS - units of work that are not meant to be interrupted
    - If interrupted they must be abandoned or finished before moving on
- Planning unit - social unit
  - Meaningful units of work composed of unit tasks
  - Used for planning work activities
  - Used to manage interruptions and task switching

6

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Planning Units

- Planning
  - Each planning unit is associated with a set of constraints
  - Plans are made by assigning planning units to groups or individuals
- Interruptions
  - Planning units can be interrupted
  - Unit task is completed or abandoned
  - New planning unit is selected based on constraints
  - The new planning unit may have already been worked on

7

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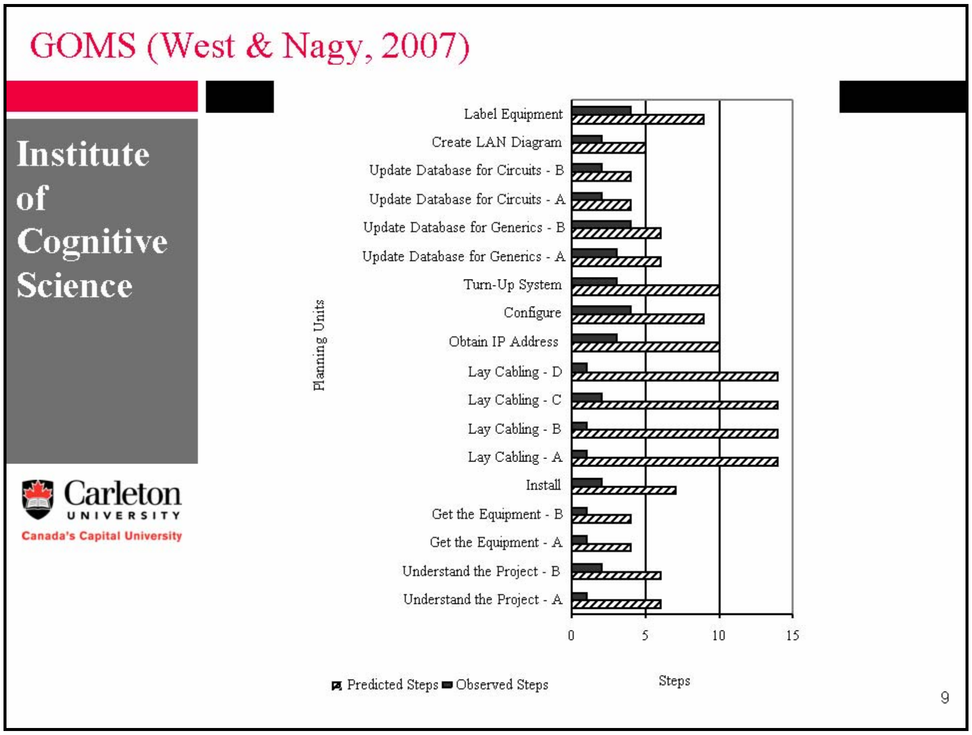
Telcom Study

- West & Nagy (2007)
  - Journal of Cognitive Engineering and Decision Making, Issue 2
  - Tested SGOMS on network maintenance teams at a large Canadian telecommunications company

8


GOMS (West & Nagy, 2007)
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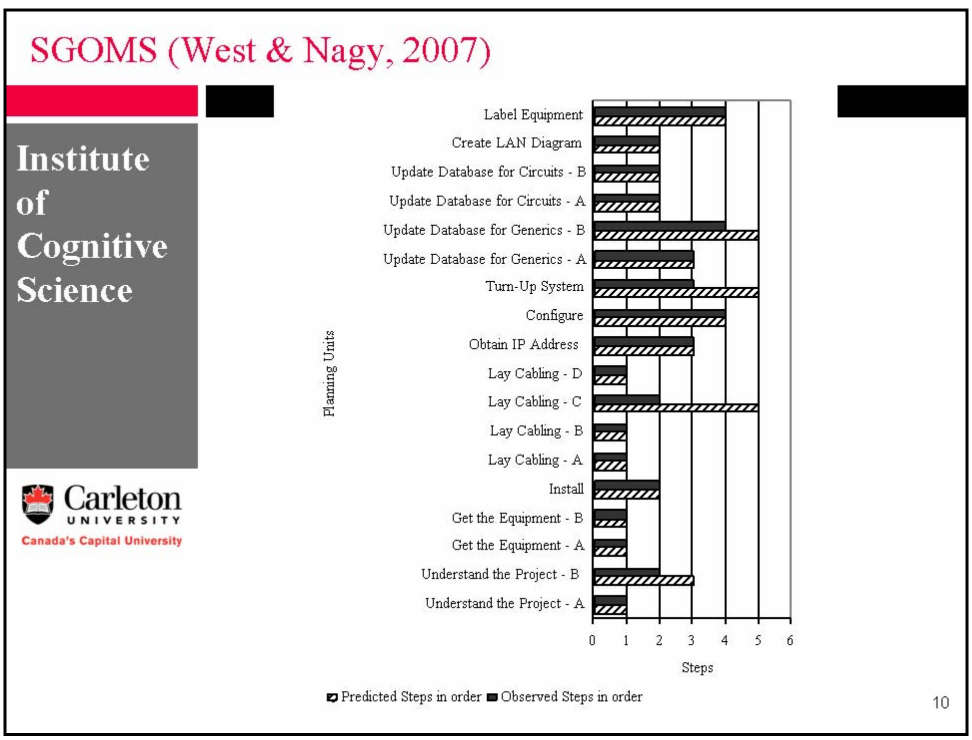
Label Equipment
Create LAN Diagram
Update Database for Circuits - B
Update Database for Circuits - A
Update Database for Generics - B
Update Database for Generics - A
Turn-Up System
Configure
Obtain IP Address
Lay Cabling - D
Lay Cabling - C
Lay Cabling - B
Lay Cabling - A
Install
Get the Equipment - B
Get the Equipment - A
Understand the Project - B
Understand the Project - A
Planning Units
0
5
10
15
Steps
Predicted Steps
Observed Steps
9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Obtain IP Address
Lay Cabling - D
Lay Cabling - C
Lay Cabling - B
Lay Cabling - A
Install
Get the Equipment - B
Get the Equipment - A
Understand the Project - B
Understand the Project - A
Planning Units
0
1
2
3
4
5
6
Steps
Predicted Steps in order
Observed Steps in order
10

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Conclusions

- Hierarchical, goal orientated task models do not predict human behavior in sociotechnical system
- These models are not wrong, just incomplete
  - They seem correct to workers because they map onto how they think about the task

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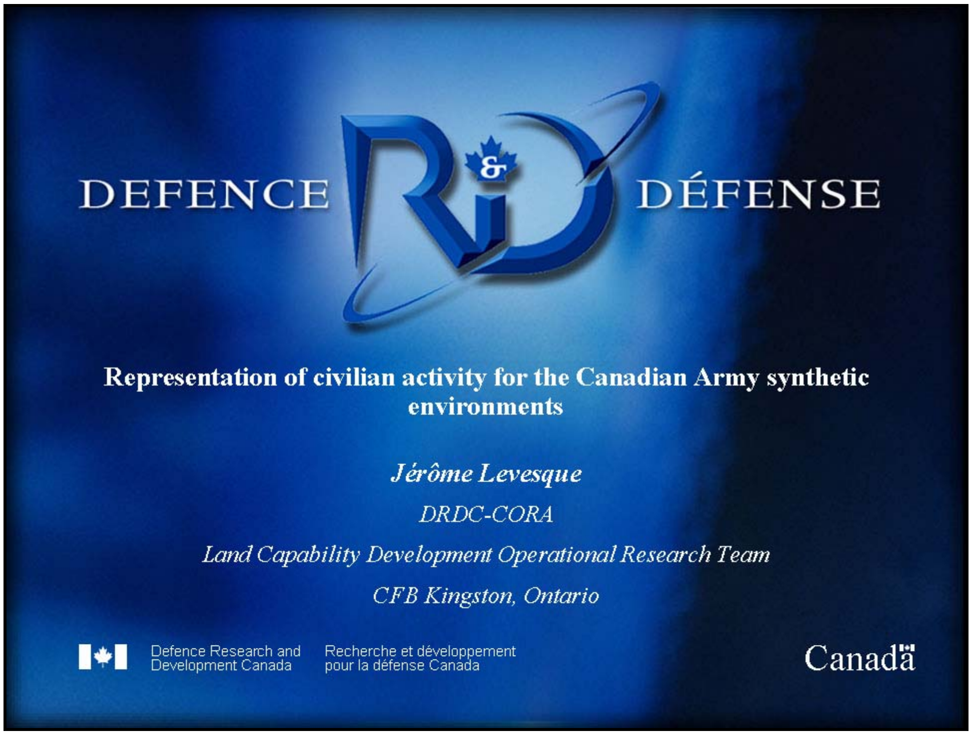
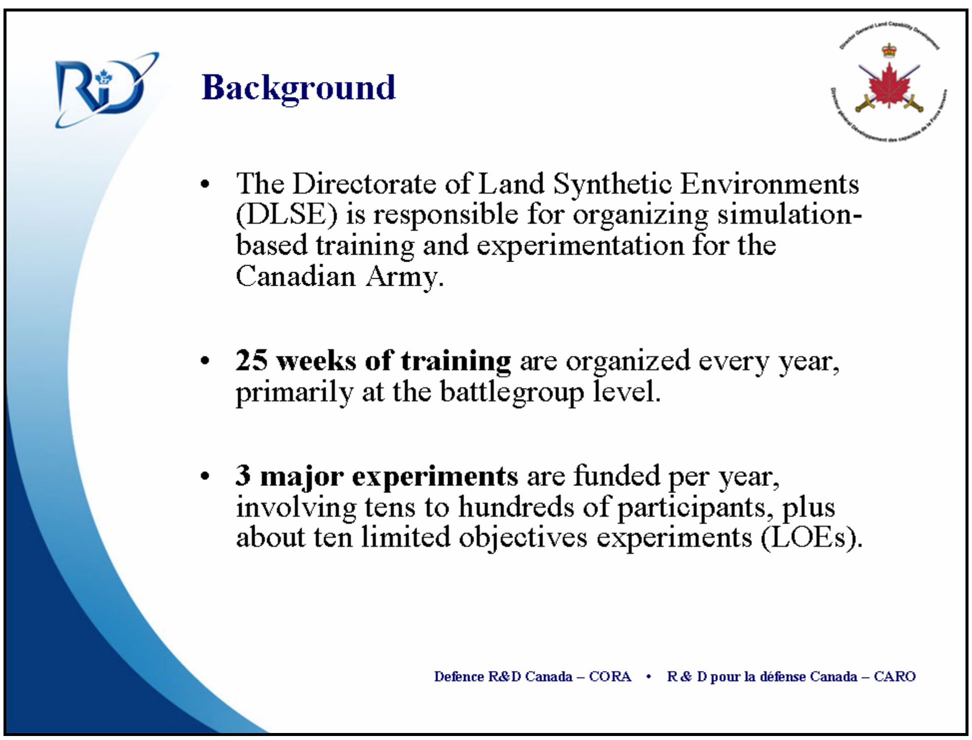
Thank You
Questions??


DEFENCE
R&D
DÉFENSE
Representation of civilian activity for the Canadian Army synthetic environments
Jérôme Levesque
DRDC-CORA
Land Capability Development Operational Research Team
CFB Kingston, Ontario
Defence Research and Development Canada
Recherche et développement pour la défense Canada
Canada


Background
• The Directorate of Land Synthetic Environments (DLSE) is responsible for organizing simulation-based training and experimentation for the Canadian Army.
• 25 weeks of training are organized every year, primarily at the battlegroup level.
• 3 major experiments are funded per year, involving tens to hundreds of participants, plus about ten limited objectives experiments (LOEs).
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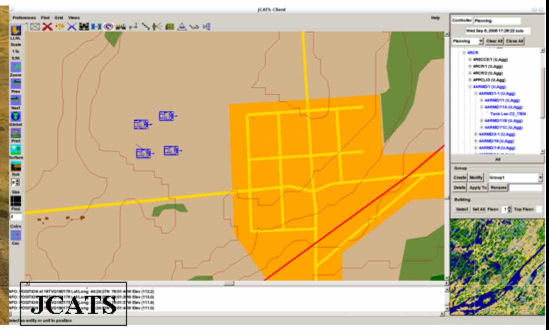
Constructive simulation software

- **JCATS**: Interactive land combat simulation war game
  - Top-down view
  - Units are represented by icons
  - Interactors decide their actions (with *lots* of left/right clicks)
  - Main differences between this war game and RTS:



Simulation of urban environments

- Urban environments involve *civilian activity*:
  - Circulation of persons
  - Urban traffic
  - Formation of crowds, disperse to dense, passive to aggressive.

  NOTE: crowd dynamics is but one aspect of civilian activity…

- Before a model is built we need to:
  - Lay down the training/experimentation objectives.
  - A software platform must be chosen.

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Designing a civilian activity model requires the assessment of several human factors

- From an experimentalist's perspective:
  - Of all the important features an actual population exhibits, which ones can reasonably be represented by an agent-based simulation?
  - Which simulation outcomes are predictive and which are not?
  - ...
- From a trainer's perspective:
  - How can we teach real-world skills using a 2D representation?
  - Which features should the 2D model exhibit to maximize the training payoff?

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The civilian activity modelling project in a glimpse

- 1 OR scientist
- Collaboration with the Royal Military College:
  - Prof. **Greg Phillips** (Comp. Eng.)
    - 1 undergrad student for 2007-2008
  - Prof. **Robert St-John** (Psychology)
  - Prof. **Allister MacIntyre** (Psychology)
    - 1 undergrad student for 2007-2008

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STORM

Socio-cultural Teamworking for OR Models

HFM-143: 30-31 May 2007

Carol Cooper Chapman

POC: Dr Beejal Mistry
bmistry@dstl.gov.uk

STORM

- Impact of social and cultural factors
- Coalition NEC context
- Investigate issues of agility
- Able to integrate with C2 models.
- Support investment decisions

30-31 May 2007

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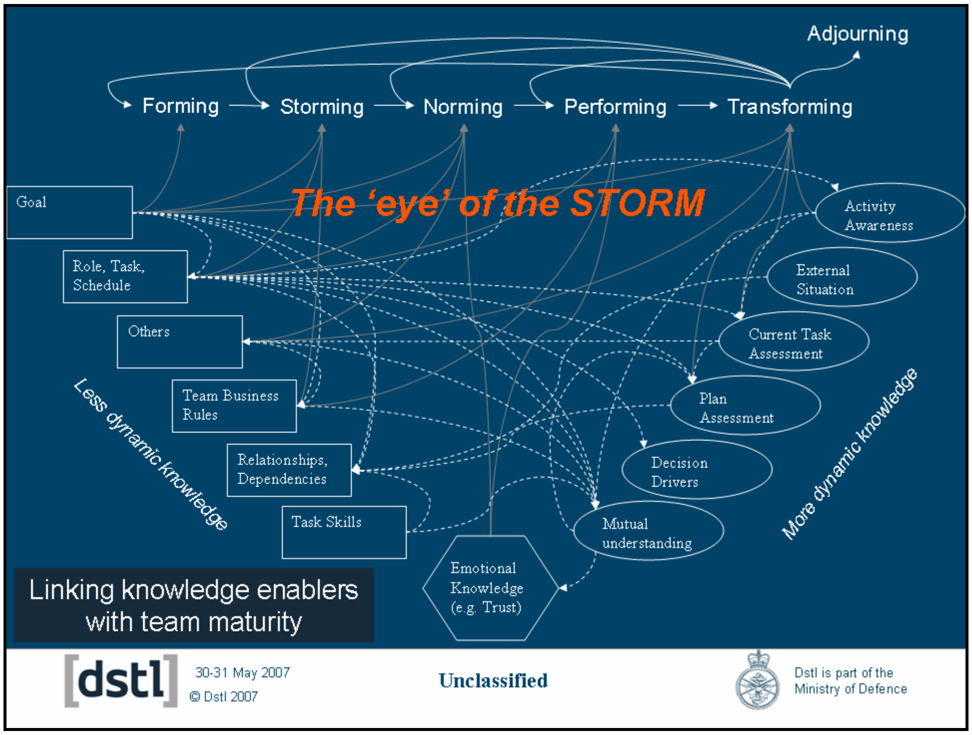

Requisite modelling

- Even if modelling human behaviour and its antecedents is difficult, **this is not an adequate reason not to.**
- Even though we may know little about the inter-relationships between key variables. **This is not an adequate reason to omit them.**

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Uncertainty in relationships

Uncertainty about relationships between variables handled through:

- Generic parametric functions
- Default: half-period sine wave.
- Substitute other functions based on evidence from sensitivity analysis or empirical validation.

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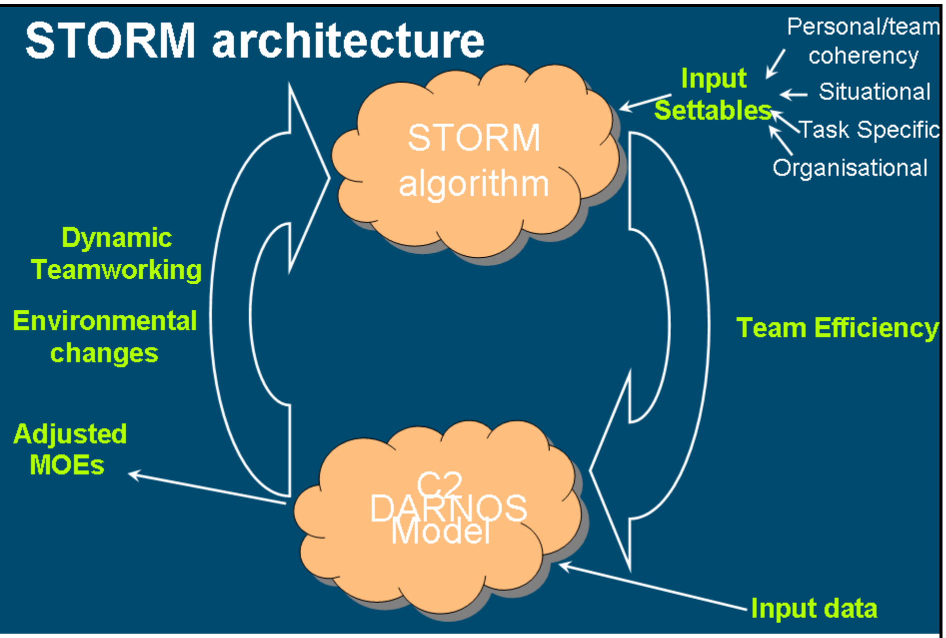
STORM architecture



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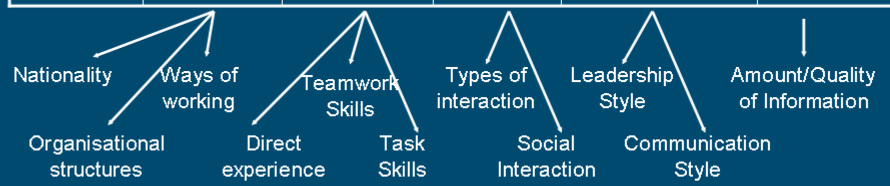
Consider 2 Teams

	HQ - Composition	Prior Exercise	HQ - Location	Commander – Leadership Style	Situation Information
Well Performing Team	UK/Aus	Considerable exercising together	Co-located	Well suited to coalition ops	Good
Poorly Performing Team	UK/Aus/ Host Nation	No exercising together	Distributed	Not suited to coalition ops	Patchy



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Results

- Well Performing Team
  - Coalition HQ well integrated
  - Collaboration timely – able to take out the threat.
- Poor Performing Team
  - Coalition HQ not well integrated well
  - Collaboration delayed – missed opportunity to take out the threat, resulting in attacks on refugee camps.

[dstl] 30-31 May 2007

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Achievement

Move towards dynamic representation of the impact of social and cultural factors affecting performance.

POC: Dr Beejal Mistry
bmistry@dstl.gov.uk

[dstl] 30-31 May 2007

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7. Presented at/Sponsored by

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Guidelines	Modelling	Simulation
Human behaviour	Operational effectiveness	Situational awareness
Human factors engineering	Operations research	Task analysis
Methodology	Requirements	Tools
Metrics		

14. Abstract

A technical evaluation was undertaken on the Specialists' Meeting HFM-143/RSM on "Human Behaviour Representation (HBR) in Constructive Modelling". The meeting focused on the need to incorporate a wide-range of Human Behavioural Representations into constructive simulations of complex, non-kinetic, operations involving a mix of military and civilian organizations. NATO RTO should address the deficiency in tools for advanced model development.

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