

# REPORT DOCUMENTATION PAGE

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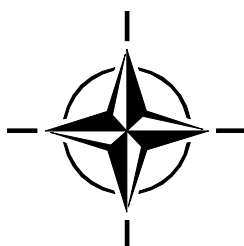
**RTO MEETING PROCEEDINGS**

**MP-HFM-202**

# **Human Modelling for Military Application**

(Applications militaires de la modélisation humaine)

Papers presented at the RTO Human Factors and Medicine Panel (HFM)  
Symposium held in Amsterdam, Netherlands on 18 to 20 October 2010.



Published October 2010

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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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# Human Modelling for Military Application

## (RTO-MP-HFM-202)

### Executive Summary

Over this first decade of the 21st Century the Human Factors and Medicine Panel (HFM) of NATO's Research and Technology Organisation (RTO) has initiated and completed a highly successful series of Technical Activities on advancing the science, the options for applications and the state-of-practice in the challenging arena of modeling humans in military activities (e.g., HFM-020, -121, -127, -128, -133, -138, -142, and, -143). Human cognition, physical/physiological moderators of behavior, organizational and command environments have been explored to advance the practice of developing models, simulations and, sometimes, simulators. The HFM-202 Symposium provided a timely and successful venue to set a framework for future HFM work on traditional human modeling and extended the scope into the emerging arena of modeling societies and cultures. In addition the Symposium's technical contributions are highly relevant to the RTO's Systems, Analysis and Studies (SAS) Panel and the NATO Modeling and Simulation Group (NMSG).

The Symposium's Program Committee set five goals for this technical activity. Four of the five goals had adequate treatment by the 43 technical presentations; the fifth goal was not treated due to a lack of presentations. A sixth goal emerged for the Symposium – the exchange of information across relevant NATO RTO Panels. This sixth goal was clearly met both by the tri-Panel participation in Symposium program development and by the technical papers and active discussions from members of SAS and NMSG.

The significant and new contributions realized from this Symposium are in 3 areas – first is the beginning of dialogue on the human science base for social-cultural modeling. This dialogue includes specific new guidance on model design and development as well as the necessary elaboration of architectural concerns, validation processes and criteria. Second is in the traditional area of human factors modeling for equipment design with new techniques for human-in-the-loop modeling inclusive of consideration of organizational variables. And third is in the area of physiological moderators of human behavior where new mathematical algorithms are now available for incorporation into relevant M&S applications.

Several papers offered insightful advice to NATO, HFM, SAS and NMSG on Research and Technology (R&T) issues that should be addressed in order for Modeling and Simulation (M&S)-based capability to be advanced in the NATO context. Additional advice was offered on processes for insuring that NATO M&S is based in science and theory as well as in rigorous review and validation. Taken in aggregate, the advice is timely and should allow NATO to advance the state-of-practice in military M&S by initiating new elements in the Programs of Work across relevant RTO Panels. Finally, the momentum of the “active dialogue” generated by this Symposium should be continued in the form of a recurring, annual NATO Research Workshop on human modeling – advances in science and application. The HFM Panel was encouraged to expediently develop a Technical Activity Proposal (TAP) for this and to include SAS and NMSG in the TAP development.

# Applications militaires de la modélisation humaine

## (RTO-MP-HFM-202)

### Synthèse

Au cours de cette première décennie du XXI<sup>ème</sup> siècle, la Commission des Facteurs Humains et de la Médecine (HFM) de l'Organisation pour la Recherche et la Technologie de l'OTAN (RTO) a initié et effectué une série très satisfaisante d'activités techniques sur les progrès de la science, les options pour les applications et l'état-de-la-pratique dans le domaine difficile des applications militaires de la modélisation humaine (par exemple, HFM-020, -121, -127, -128, -133, -138, -142, et, -143). La connaissance humaine, les modérateurs physiques/physiologiques du comportement, les environnements organisationnels et de commandement ont été explorés pour faire progresser le développement des modèles, des simulations et, quelquefois, des simulateurs. Le symposium HFM-202 a été le lieu d'établissement réussi en temps opportun d'un cadre de travail pour les futurs travaux HFM sur la modélisation humaine et a étendu le champ d'action dans le domaine émergent de la modélisation des sociétés et des cultures. De plus, la contribution technique du symposium a été très précieuse pour la Commission sur les Etudes et l'Analyse de Système (SAS) de la RTO et le Groupe de Modélisation et Simulation de l'OTAN (NMSG).

Le Comité de Programme du Symposium avaient fixé cinq buts pour cette activité technique. Quatre d'entre eux ont eu un traitement adéquat avec 43 exposés techniques. Le cinquième but n'a pas été traité suite à un manque d'exposés. Un sixième but est apparu au Symposium – l'échange d'informations entre les Commissions RTO. Le sixième but a clairement été atteint à la fois par une participation tri-Panel dans le développement du programme du Symposium et aussi par les documents techniques et les débats actifs des membres de SAS et du NMSG.

C'est dans 3 domaines que se situe la contribution nouvelle et significative réalisée par ce Symposium. Le premier concerne le début d'un dialogue sur la base des sciences humaines pour la modélisation socio-culturelle. Ce dialogue comprend des directives nouvelles spécifiques aussi bien sur la conception et le développement d'un modèle que sur l'élaboration nécessaire des problèmes architecturaux, des procédés et des critères de validation. Le second est le domaine traditionnel de la modélisation des facteurs humains pour la conception des équipements avec de nouvelles techniques pour « l'homme-dans-la-boucle » incluant des considérations sur les variables organisationnelles. Et le troisième est le domaine des modérateurs physiologiques du comportement humain où des nouveaux algorithmes mathématiques sont actuellement disponibles pour leur incorporation dans les applications M&S concernées.

Plusieurs documents ont proposé des recommandations pertinentes à l'OTAN, à HFM, SAS et au NMSG sur les questions relatives à la Recherche et la Technologie (R&T) qui doivent être traitées afin d'améliorer les capacités basées sur la modélisation et la simulation (M&S) dans le contexte de l'OTAN. Une recommandation supplémentaire a été faite sur les processus qui permettent de s'assurer que la M&S de l'OTAN est basé aussi bien sur la science et la théorie que sur des revues et des validations rigoureuses. Globalement, cette recommandation est opportune et doit permettre à l'OTAN de progresser dans l'état-de-la-pratique concernant le M&S militaire en introduisant de nouveaux éléments dans les Programmes de Travail des commissions RTO concernées. Finalement, la dynamique de « dialogue actif » engendrée par le Symposium doit être poursuivie régulièrement sous la forme d'un atelier de recherche annuel de l'OTAN sur les progrès des sciences et applications de la modélisation humaine. La commission HFM a été encouragée à développer une Proposition d'Activité Technique (TAP) adaptée sur ce sujet et d'inclure SAS et NMSG dans le développement de cette TAP.

## Technical Evaluation Report

**Robert E. Foster, Ph.D.**

1691 N. Birch Street, Canby, Oregon 97013  
USA  
Tel: +1.971.275.5090

[BOBFOSTER10@CANBY.COM](mailto:BOBFOSTER10@CANBY.COM)

### 1.0 INTRODUCTION

Advances in modeling and simulation (M&S) for military applications is evolutionary in nature with roots at the tactical level with early 20<sup>th</sup> century aircraft simulations (for training<sup>1</sup>) and at the operational planning level with the elaboration of operations analysis techniques (rooted in the mathematics-centered analytic methods arising from World War I analyses by Lanchester<sup>2</sup>). Recent requirements for research and technology development in M&S have come from the realities of NATO operations in Kosovo, Afghanistan and various other non-traditional military missions<sup>3</sup> in areas of conflict where military, peacekeeping and nation building strategies have to be blended into whole-of-government plans informed by operations and intelligence analysis. These new missions are also a challenge for the development of human science that supports the M&S tools of analysts and planners.

This Symposium was organized to consider the state-of-human science and its application to M&S technology, and to make recommendations to NATO on making science-based M&S tools available for military application. The Program Committee set five goals for this Research Symposium:

- To make an inventory of operational demands for Human Factors based support;
- To identify researched pathways to solutions;
- To identify knowledge challenges and technical challenges for integrated model development;
- To set high level guidelines for human modeling integration; and
- To define NATO's perspectives on exploitation of human integrated operational modeling<sup>4</sup>.

Forty three technical papers (24 podium; 14 posters; 5 keynotes) were scheduled, representing research and development efforts in eight nations (six NATO and 2 PfP nations). The Symposium convened in Amsterdam at "The Naval Barracks Amsterdam" from Monday, 18 October to Wednesday, 20 October 2010.

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<sup>1</sup> "Dry Shooting for Airplane Gunners - Popular Science Monthly". January 1919. p. 13-14.

<sup>2</sup> Lanchester F.W., Mathematics in Warfare in The World of Mathematics, Vol. 4 (1956) Ed. Newman, J.R., Simon and Schuster, 2138-2157

<sup>3</sup> So-called non-traditional missions/operations arising since the mid 1990s may become the new normal for NATO operations in the 21<sup>st</sup> century and thus the timeliness of the Symposium is remarkable.

<sup>4</sup> This was the Symposium's only non-R&T goal and it unfortunately did not elicit an adequate response from potential authors.

## 2.0 TECHNICAL EVALUATION

This Technical evaluation will be organized into 3 sections: the Symposium organization and venue, the framework set by keynote papers, and the technical content of the presentations. The keynote presentations and the technical papers provide significant new advice to NATO on human modeling in M&S applications. The report will end with a summary of the 4 recommendations offered to the Human Factors and Medicine Panel for consideration.

### A. Symposium Organization –Themes, Presentations and Venue

The Symposium’s goals were largely met by the Program Committee’s selections of 43 papers and poster topics. Blending the presentations into 5 sessions with an “analysis and discussion” segment (led by a Program Committee member) at the end of each session led to both general participation of authors and audience, and to insightful new information about both progress in M&S and challenges for modeling non-traditional warfare and military missions. Interestingly the Program Committee “seeded” the presentation agenda with papers by very senior scientists and practitioners in modeling<sup>5</sup>. This was highly successful in generating wide ranging discussions of modeling history and approaches to a new era in modeling, as well as providing some real time mentoring to the younger presenters on how to successfully approach complex modeling problems.

The open dialogue resulting from the ‘analysis and discussion’ sessions served to provide some cross-discipline interchanges but often the semantic barriers inherent to the various modeling disciplines hindered deeper exchanges of information. This can only be corrected if NATO supports an ongoing exchange through periodic multidisciplinary meetings such as this (see TER Recommendation #3 below). While the Symposium’s program had highly relevant themes, these generic themes were only marginally served by the actual papers presented (possibly as a result of the nature of a Research Symposium with its unconstrained ‘open’ call for papers). Nonetheless, the Symposium’s open discussions demonstrated a good understanding of common needs across the various modeling environments. Thus, if NATO desires to continue an active dialogue on human modeling either the specialist meeting format or the workshop format should be a better venue in that these activities allow the organizers to request specific contributions from experts.

The Symposium was augmented and well served by an excellent venue provided by the Dutch organizers. The Symposium’s meeting room and excellent audio-visual support were very conducive to discussions and the provision for lunches on site provided extra opportunities for participant discussions.

**TER Recommendation 1:** Future HFM Symposia should seek to have formal analysis and discussion sections fitting within the theme structure of the meeting. As appropriate these analyses and discussions could be summarized and included in Symposium proceedings by the Symposium Chairs.

### B. Framing the Issues – the Keynotes

The keynote presentations of this Symposium set the “users” context for human modeling. The “users” in this case were of several types: military operators (LtGen van Loon for flag officer operational-strategic level issues; Col Swillens for tactical level insights), military operations analysts (LTC Hudak), and M&S architectures (Dr. Numrich).

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<sup>5</sup> See papers by Levis (2), Numrich, Starr et al., Lotens et al., Jones (2), Belyavin, and Lebiere et al.

- LtGen van Loon opened the Symposium with a very practical exposition of human behaviors in current military operations inclusive of both the deployed force and the staff elements of NATO. The General's message to the human modeling community based on his considerable experience with non-traditional military operations (e.g., Kosovo and Afghanistan) suggests that human behavior models should be able to address a) individual, organizational and interoperability dynamics in the multi-national military teams; b) operational complexity, scalability, uncertainty in a blended military, local and regional language and cultural context; c) understanding human dynamics at individual, group and systems (institutional); and d) preparing the NATO force by training for current operational complexities.
- Col Swillens, in the "engagement" keynote presentation, provided an elaboration LtGen van Loon's message by exposing military tactical concerns for analysis and training of battalion-level military formations. Col Swillens highlighted how even local events raise the complexity of international cooperation such as in negotiations with the local authorities, and the complexity of planning given the reality of troops on site in contrast to the perspectives of Operations personnel in somewhat remote Operations rooms thereby putting the burden of complexity and confusion on local site commanders.
- Representing the military operations analysis perspective with a practical 'use case' of the need for a modeling capability to support the analytic demands of military leaders, Dr. (LTC) Hudak provided an excellent example of the non-kinetic modeling problem for current operations in Afghanistan's Helmand Province. Utilizing the agent-based modeling environment based on a conflict driver/ecosystem theory, Dr. Hudak outlined how the US Army is beginning to develop a M&S capability in this domain.
- Architectural challenges for modeling the military operations environments outlined by LtGen van Loon and Col Swillens were highlighted in Dr. Numrich's keynote. She emphasized the need to attend to design and implementation challenges of modeling environments contrasting the demands of large constructive simulation environments, running under High Level Architecture (HLA) standards, with simulations of social-cultural phenomena developed with new modeling methodologies (e.g., agent based models of complex adaptive systems) heretofore not part of the constructive simulation portfolio.

Taken as a whole these keynote presentations were very successful in setting some essential attributes for achieving success in the application of human modeling for analysis and planning in the scope of current military operations. Indeed, the context thus set is highly relevant to NATO ACT's development and analysis of technology options to meet NATO's Long Term Capability Requirements (LTCRs).

**TER Recommendation #2:** Relevant RTO Panels and HFM Panel Chairman should consider the content of these keynote presentations to be highly relevant to NATO's Long Term Capability Requirements (LTCRs). In that context the Symposium's program Committee should assess all LTCRs and provide input to the responsible LTCR lead Panel for updating relevant LTCR roadmaps.

### **C. Symposium Technical Content**

The presentations and papers contained in the Symposium Proceedings have application to one or more of three (3) general capability areas for M&S – military analysis and assessment (both for operations and intelligence), training (for all levels of operation inclusive of personnel and organizational skills), military systems development and acquisition (for weapons systems, personal equipment, military organizational variables).

- 1) Military analysis and assessment. Military course of action analysis and operations plans development for current operations may be the most pressing “demand signal” for advances in human modeling. Of particular importance to the success of the Symposium were the several papers summarizing a) the state-of-practice in an area of application or in a NATO nation’s analytic enterprise and b) the NATO technical activities either ongoing or in the past that contribute to the capability development in M&S. These contexts generated very important discussions.

Within this context, the largest number<sup>6</sup> of papers, posters and keynotes addressed the emergence of non-kinetic military mission as a driver for new modeling technologies. This is the area of modeling teams, organizations, government actions, societies, cultures and the resulting military contributions for non-traditional operations (e.g. peacekeeping). While these papers presented the current practice of agent based modeling and the use of Bayesian network analyses, there was little exposition of the larger body of research on models of human behavior which might be essential for robust social-culture modeling. To that end, it would have strengthened the discussions if the Program Committee had sought papers from other modeling disciplines such as system dynamics or game theory modeling. It is indeed the case that the procedures for Research Symposia limit the Program Committee’s discretion to solicit specific contributions (see Recommendation #3). On the other hand and very positively, there was a robust discussion of model architectures that yielded several key insights to achieve progress in this capability area –

- A need for research and technology development for the vertical interoperability of models (vertical across the levels of military operation; tactical-operational-strategic);
- A need to integrate (or aggregate) models and their outputs across the dimensions of individual human models-to-organizations-to-societies-to-cultures;
- A need for the development of model architectures and approaches to modeling validation that can be used for hybrid modeling environments (hybrids using agent, systems dynamic, game theoretic models);
- New approaches to dealing with the dynamics of military missions where the dimensions of time can vary from seconds (in weapons system tactical modeling) to months-years in sociocultural modeling; and
- The disciplined validation methods of the UK (GBR) can be a good start for addressing social science contributions to the traditional operations research methods and for assessing the suitability (“fit-for-purpose” assessment) of model-based analysis methods.

With these insights in mind, it is apparent that this Symposium represented the very beginning of NATO’s critical dialogue on the need for a science base on sociocultural modeling. It also was apparent that much discussion and technical interchange is needed to frame and begin the development of criteria, processes and the technology of multilevel modeling architectures and validation strategies.

- 2) Training. The papers<sup>7</sup> presented on advances in this general capability area represent continued progress in the rich history of M&S application. This continuing progress is vital to NATO militaries in that M&S is a key to the development of those essential military knowledge, skills and competencies essential for NATO’s operational success. Training military personnel may be the

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<sup>6</sup> See the following papers: Hudak and Baez; Numrich; Clemente; van Vliet; Wittmann et al.; Levis (2); Jones (2); van Hemert et al.; Svenmark et al.; Starr et al.; Lebiere et al.; Schaub; de Reus et al.; Caldeira-Hankey et al.; Lotens et al.; Leiberg et al.; Woodill et al.; Dhondt et al.; and Ubink et al.

<sup>7</sup> See the following papers: Levesque et al.; Hoover et al.; Kramer et al.; Dobbins and Myers; van Diggelen et al.; Lotens et al.; Baker et al.; Belyavin and Cain; Ubink et al.; Abdellaoui et al.; and, Woodill et al.

largest continuous demand for M&S since realistic live training venues are very costly and cannot be used for the full spectrum of knowledge and skill generation/maintenance demanded by the challenges of non-traditional military operations currently being conducted by NATO.

Of note were the presentations outlining efforts to include societal and cultural behavior models into training systems. This new theme and demand from military readiness training venues responds to the reality of the current NATO “operational environments”. Here the challenges seem to lie in the question of ‘what human behaviors’ are relevant and how to adjust cognitive models to represent the diversity of behaviors on the scale of societies and cultures. Scaling individual cognitive model architectures such as SOAR and ACT-R to this level will remain a significant challenge for the foreseeable future.

Two other contributions to this capability area are noteworthy. First was the continuation of a dialogue on how to approach team and organization modeling such that robust team members and organizational variables can be included in simulation environments. This area will remain a challenge and a continued cross-NATO dialogue of experts should continue. Second is in the domain of behavior moderators. Important new algorithms were presented that can insert into human behavior models moderators for heat strain and fatigue, hydration levels, and terrestrial altitude effects. Of course these moderators are but a small set of all behavior moderators. Indeed, from the results of HFM-128 we know that the NATO’s human behavior modeling M&S practitioners believe that behavior moderators can be developed for such high level functions as decision making and other interpersonal interactions and behaviors. A continuing dialogue is necessary to develop and harmonize behavior moderator algorithms across the NATO M&S community in order to engender wider application of these important innovations.

- 3) Development and acquisition of “military systems”. M&S tools have been essential and key to the modernization of military organizations, equipment and processes. The pace of technological innovation demands the continuing development of models for assessing the human element in the system itself (e.g., the human operator of a command and control workstation) and in the organization that employs a mélange of personnel of varying roles depending on the missions and the structural characteristics of the force controlling or conducting the mission. The papers<sup>8</sup> supporting advancements in this general capability area demonstrated important new M&S contributions such as the following:

- New insights on how to design workstation interfaces that are dependent of spatial Information;
- updated mathematical models for water demands of personnel and the effects of altitude on performance;
- An approach to instantiating virtual partners in systems design; and
- New command-and-control attributes for human terrain reasoning.

Taken as a whole, the technical content of this Symposium offers NATO new and important knowledge. The exploitation of this knowledge should provide new opportunities for improved operational capabilities. Two recommendations result from consideration of the technical presentations and discussions.

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<sup>8</sup> See the following papers: Park et al.; Alexander et al.; Sennersten et al.; Beidleman et al.; Chevront at al.; Belyavin et al.; van Doesburg et al.; Woodill et al.; Khudetsky et al.; Ubink et al.; and, Winkelholz et al.

**TER Recommendation #3:** Exploit, engender and continue the momentum of scientific and technical dialogue begun at this Symposium and enable the development of a professional network of scientists and practitioners through a recurring technical exchange venue -- such an annual NATO Research Workshop on Human Modeling in NATO M&S applications. The HFM Chairman (alone or in consultation with the Chairmen of SAS) should expediently develop a Technical Activity Proposal (T.A.P.) for a recurring activity.

**TER Recommendation #4:** The issues of a) vertical and horizontal integration of multiple models and b) the dynamics of time (i.e., models handling time scalable from minutes to months/years) should be addressed in any new, relevant M&S technical activities of RTO. Both the science and theories underpinning human modeling as well as the structural conventions and computer science issues of combining multiple models must be advanced in order to provide NATO with advanced capabilities in M&S.

### D. Recommendations

Important progress in NATO M&S can be realized through continuing multinational exchanges of scientific and technical advances especially in the area of improving capabilities for non-traditional missions. A future program of R&T activities would be assisted by HFMP implementing the following 4 recommendations.

- 1) Future HFM Symposia should seek to have formal analysis and discussion sections fitting within the theme structure of the meeting. As appropriate these analyses and discussions could be summarized and included in Symposium proceedings by the Symposium Chairs.
- 2) Relevant RTO Panels and HFM Panel Chairman should consider the content of these keynote presentations to be highly relevant to NATO's Long Term Capability Requirements (LTCRs). In that context the Symposium's program Committee should assess all LTCRs and provide input to the responsible LTCR lead Panel for updating relevant LTCR roadmaps.
- 3) Exploit, engender and continue the momentum of scientific and technical dialogue begun at this Symposium and enable the development of a professional network of scientists and practitioners through a recurring technical exchange venue -- such an annual NATO Research Workshop on Human Modeling in NATO M&S applications. The HFM Chairman (alone or in consultation with the Chairmen of SAS) should expediently develop a Technical Activity Proposal (T.A.P.) for a recurring activity.
- 4) The issues of a) vertical and horizontal integration of multiple models and b) the dynamics of time (i.e., models handling time scalable from minutes to months/years) should be addressed in any new, relevant M&S technical activities of RTO. Both the science and theories underpinning human modeling as well as the structural conventions and computer science issues of combining multiple models must be advanced in order to provide NATO with advanced capabilities in M&S.