



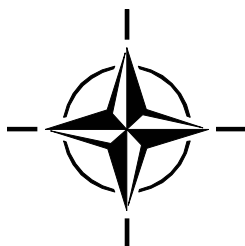
**RTO TECHNICAL REPORT**

**TR-SAS-053**

# **Virtual Institute on Human Behavior Representation**

(Institut virtuel de représentation  
du comportement humain)

Final Report of Task Group SAS-053.



Published June 2010





RTO TECHNICAL REPORT

TR-SAS-053

# **Virtual Institute on Human Behavior Representation**

(Institut virtuel de représentation  
du comportement humain)

Final Report of Task Group SAS-053.

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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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# **Virtual Institute on Human Behavior Representation**

## **(RTO-TR-SAS-053)**

### **Executive Summary**

The topic and focus of the SAS-053 was extended and extrapolated from a previous NATO Long Term Scientific Study (LTSS/51) on Human Behavior Representation sponsored by the SAS Panel. The purpose of the LTSS was to provide a report for the use by NATO and national authorities on the implications of technological developments to military operations over the next ten to fifteen years and to provide research planners with recommendations for research that address/investigate the implications of projected technological developments. Of particular interest to this project, under LTSS/51, their recommendation of highest priority was to establish a NATO RTO exploratory team to investigate the feasibility and utility of assembling a virtual institute for research on human behavior modeling (NATO, 2001). Specifically, the virtual institute was to be established for the purpose of modeling military-related individuals, teams, groups, platforms, and organizations in their performance of military operations and tasks. The virtual institute was envisioned as a NATO resource that would accelerate technology dissemination in specific technology areas that would include development of a web-based clearing house of databases, models and model components and developing standards, and requirements to support multi-national research on human behavior modeling.

The objective of SAS-053 was two-fold. Firstly, SAS-053 is to advise the SAS Panel and, through cooperation with other RTO Panels, the RTO on the technical merit and feasibility of establishing a virtual institute within NATO. Secondly, the SAS-053 is to advise the SAS Panel and, through cooperation with other RTO Panels, the RTO on the feasibility of enabling multi-national research and development in human behavior modeling by using the virtual institute concept. The SAS-053 is able to present three findings. The first finding is that the virtual institute concept has sound technical merit and its technological foundations are growing stronger due to commercial sector technology developments. The second finding is that the virtual institute concept is viable, feasible, and shows great promise for providing research cost savings and improved international research collaboration. The third finding is that the virtual institute concept is an advisable means for conducting international, multi-cultural research in human behavior modeling.

As a first step, meetings were held to discuss technical feasibility of the concepts, to conduct technical interchange and to assess NATO-wide support for the concepts. In addition, team members participated in their individual countries' technical activities related to the two concepts in order to assess their own countries' technical experts' opinions concerning the concepts as well as support for the concepts and commitment to their execution. A final thrust was to organize and prepare to assess developments of the technological foundations needed to implement and operate a virtual institute.

In brief, there is support for the concepts; the technologies needed to implement the concepts are available and have been, in many cases, demonstrated; and there is widespread belief that the NATO community would benefit from the virtual institute concept and that human behavior representation is one of many research arenas that would benefit by exploiting the virtual institute. There are a number of promising follow-on projects that a follow-on Panel should pursue in the areas of human behavior modeling research and uses of the virtual institute. A key activity for the virtual institute should be the development of

improved human behavior models. Improvement in human behavior models requires research on the incorporation of multiple skill levels and representations of doctrine and they must reflect societal, training, and educational differences. Behavior moderators such as morale, fatigue, stress, fear, information operations, and intent must be modeled and included within the human behavior model. We also believe that these projects can be given focus and provide demonstrable utility by producing a tool that could be used among the nations; our suggestion is the development of a multi-national, coalition submarine warfare simulation environment. This environment would provide opportunities for cultural and team research, modeling and simulation within each submarine as well as for cross-cultural and multi-national modeling and simulation in the command and control of submarine operations.

# **Institut virtuel de représentation du comportement humain (RTO-TR-SAS-053)**

## **Synthèse**

Le sujet et le cadre du SAS-053 ont été élargis et extrapolés à partir d'une précédente étude scientifique à long terme (LTSS/51) de l'OTAN, consacrée à la représentation du comportement humain et sponsorisée par la commission SAS. Cette LTSS avait pour objet de soumettre un rapport à destination de l'OTAN et des autorités nationales, portant sur les implications des développements technologiques pour les opérations militaires dans les dix à quinze prochaines années, et de fournir aux responsables de la planification des recherches des recommandations pour les recherches abordant/étudiant les implications des développements technologiques prévus. D'un intérêt tout particulier pour ce projet, la recommandation la plus prioritaire de la LTSS/51 concernait la mise en place d'un groupe d'étude RTO OTAN chargé d'analyser la faisabilité et l'utilité de la création d'un institut virtuel de recherche sur la modélisation du comportement humain (OTAN, 2001). Plus spécifiquement, cet institut virtuel devait avoir pour vocation de modéliser l'accomplissement de tâches et d'opérations militaires par des personnes, équipes, groupes, plates-formes et organisations en rapport avec l'armée. L'institut virtuel était envisagé comme une ressource de l'OTAN permettant d'accélérer la diffusion technologique dans des domaines technologiques précis, et comprenait le développement d'un centre d'échange en ligne de bases de données, de modèles, de normes de développement et éléments de modèles, et des besoins relatifs aux recherches multinationales sur la modélisation du comportement humain.

L'objectif du SAS-053 était double. Premièrement, le SAS-053 devait conseiller la commission SAS – et, par le biais de sa coopération avec d'autres commissions, la RTO – sur la faisabilité et l'intérêt technique de la création d'un institut virtuel au sein de l'OTAN. Deuxièmement, le SAS-053 devait conseiller la commission SAS – et, par le biais de sa coopération avec d'autres commissions, la RTO – sur la possibilité de permettre la recherche et le développement multinationaux en matière de modélisation du comportement humain grâce à l'emploi du concept d'institut virtuel. Le SAS-053 est en mesure de présenter trois conclusions. La première conclusion est que le concept d'institut virtuel représente un intérêt technique certain et que les progrès de la technologie du secteur commercial renforcent en permanence ses fondements technologiques. La deuxième conclusion est que le concept d'institut virtuel est viable, réalisable et également très prometteur quant à la réalisation d'économies et l'amélioration de la collaboration internationale dans le domaine de la recherche. La troisième conclusion est que le concept d'institut virtuel est un procédé que l'on peut recommander pour mener des recherches internationales et multiculturelles sur la modélisation du comportement humain.

Dans un premier temps, plusieurs réunions ont été tenues en vue d'étudier la faisabilité technique des concepts, de procéder à des échanges techniques et d'évaluer le soutien recueilli par ces concepts au niveau de l'OTAN. En outre, certains membres du groupe ont participé aux activités techniques de leur pays relatives aux deux concepts afin d'évaluer les avis de leurs « experts techniques » nationaux sur ces questions, ainsi que le soutien recueilli par ces concepts et les engagements pris pour leur mise en œuvre. La dernière initiative a consisté à organiser et préparer l'évaluation des développements des fondements technologiques nécessaires à la mise en œuvre et à l'exploitation d'un institut virtuel.

En résumé, ces concepts trouvent un certain soutien ; les technologies requises pour leur mise en œuvre existent et ont été éprouvées dans de nombreux cas ; et il est largement admis que la communauté de

l'OTAN profitera de ce concept d'institut virtuel et que la représentation du comportement humain est l'un des nombreux domaines de recherche qui bénéficieraient de l'exploitation de l'institut virtuel. Un certain nombre de projets inhérents prometteurs devraient être approfondis par une commission de suivi dans les domaines de la recherche sur la modélisation du comportement humain et des utilisations de l'institut virtuel. L'une des activités essentielles de l'institut virtuel devrait être le développement de modèles de comportement humain plus perfectionnés. L'amélioration des modèles de comportement humain nécessite des recherches sur l'incorporation de plusieurs niveaux de compétences et de représentations de doctrines ; ces modèles doivent également refléter les disparités liées à la société, la formation et l'éducation. Les modérateurs de comportement tels que le moral, la fatigue, le stress, la peur, les opérations cognitives et l'intention doivent être modélisés et intégrés dans le modèle de comportement humain. Nous pensons également que ces projets peuvent faire l'objet d'une attention particulière et s'avérer utiles en fournissant un outil que les nations pourront employer ; nous suggérons le développement d'un environnement de simulation multinational de guerre sous-marine de la coalition. Un tel environnement favorisera la modélisation, la simulation et les recherches culturelles et par équipes au sein de chaque sous-marin, ainsi que la modélisation et la simulation interculturelles et multinationales lors du commandement et du contrôle des opérations sous-marines.

## **Overview: SAS-053 FINAL PROJECT BRIEFING**



### **NATO RTO SAS-053 Virtual Institute for Research on Human Behavior Representation**

## **Final Report**

Dr. Sheila Banks, Co-Chair, USA  
Dr. Uwe Dompke, Co-Chair, NC3A  
SAS Panel Meeting, 23 Oct 2007  
Athens, Greece



## **Presentation Overview**

- **Background**
- **TOR: Scope and Goals**
- **Participants**
- **Meetings**
- **Input to Other Activities**
- **Final Report**
  - **State of the Art HBR Team, Group, Organization**
  - **Virtual Institute Concept**
  - **Results and Lessons Identified**
  - **Recommendations**
- **Way Ahead**

23 October 2007

2



## Background

- **LTSS SAS-017 on Human Behaviour Representation (HBR) Recommendations**
  - Initiate an Exploratory Team (ET) to build up a Virtual Institute for Research on HBR
  - Initiate an Exploratory Team (ET) on a Research Plan for Team, Group and Organizational Modelling Research
- **SAS ET.V**  
**Virtual Institute for Research on HBR**
  - Combined Two Recommended Activities
  - Recommendation to Establish an RTG for a Virtual Institute with a Specific Task as Test Case (HBR)

23 October 2007

3



## Scope and Goals

- **Develop a Virtual Institute Concept for NATO**
  - Organizational
  - Technical
  - Multi-national Use and Involvement
  - Virtual Institute Metrics and Success Criteria
- **Develop a Roadmap for the Development and Use of Virtual Institutes (VI) in NATO**
- **Employ Prototype VI**
  - Assess Utility of VI Concept
  - Research on Team, Group, Organization HBR

23 October 2007

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## Membership

- 
- 
- USA**
- 
- 
- 
- NC3A**
- 
- 
- 
- Canada**
- 
- 
- 
- Germany**
- 
- 
- 
- The Netherlands**
- 
- 
- 
- United Kingdom**

23 October 2007

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## Meetings (1 of 3)

- **1st Meeting: September 2004 - NATO HQ**
  - Virtual Institute Framework
  - State-of-the-Art for Team, Group, and Organisational Modelling
- **2nd Meeting: February 2005 Orlando, USA (with SAS-050)**
  - Co-Meeting with SAS-050
  - Experiment with HFM-Panel/ACT Co-operation (HFM-138 Adaptability in Coalition Teamwork)

23 October 2007

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## Meetings (2 of 3)

- **3rd Meeting October 2005 - NC3A, The Hague**
  - Progress on State-of-the-Art Report on Team, Group, and Organisational Modelling (DEU Input)
  - Progress on VI/HBR Concept of Operation
  - VI/HBR Prototype Experiment
- **4th Meeting May 2006 - IDA, Alexandria, USA**
  - Study on Team Oriented Behaviour in MNE 4
  - State-of-the-Art Report
  - Comparison of HBR Approaches
  - Experiment LTAMC (NATO Leader and Team Adaptability in Multi-national Coalitions)

23 October 2007

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## Meetings (3 of 3)

- **5th Meeting June 2007 - IABG, Ottobrunn, Germany**
  - HFM-138 Update
  - Layout of Final Report
  - Discussion on Results Lessons Identified
  - Discussion on Recommendations

23 October 2007

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## Input to Other Activities

- **Meetings with NATO and Nations**
  - Adm Bartoli on Support for VI
  - ACT
  - US JFCOM
- **Contacts with the HBR Community**
  - BRIMS (Behavior Representation in Modeling And Simulation) Presentations
  - HFM Panel
  - Other Conferences
- **RTA VI Meeting**

23 October 2007

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## Final Report

- **Executive Summary**
- **Introduction**
- **SAS-053 Work**
- **State of the Art HBR Team, Group, Organization**
- **Virtual Institute Concept**
- **Results and Lessons Identified**
- **Recommendations**

23 October 2007

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## HBR State-of-the-Art Report

- Introduction
- Modeling Parameters in Team, Group, and Organizational Modeling
  - Preliminary Ontology Development Necessary for Recommended HFM RTG
- Usage and Applications
  - Major Applications under Development in Nations Relevant to Technology Review
  - Incorporation of Commercial Gaming Technology into Modeling Review
- Shortfalls in Modeling Applications for Team, Group, and Organizational Modeling

23 October 2007

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## Virtual Institute Concept

- Introduction
- Definition
- Underlying Technology
- Organisation of an Virtual Institute
- Usage
- Data Exchange
- Current Projects

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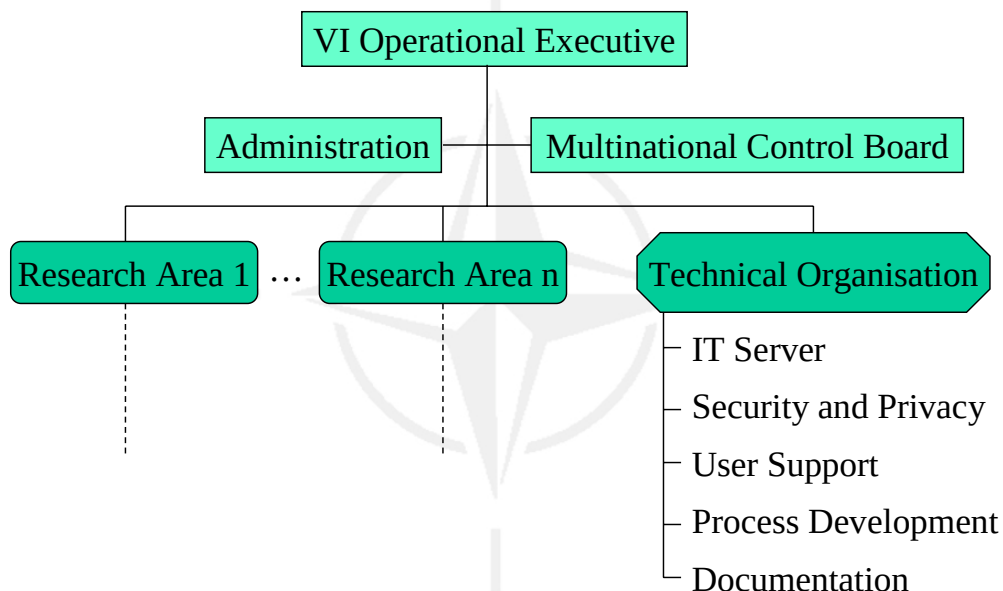
## Developments in IT/VI Technology

- Study was Recommended in 1999 and Started in 2004 - Now we have 2007!
- IT Technology now Commercially Available for Everybody (High Bandwidth, Video, Groupware, Shared Workspaces)
- Web 2.0 Developments (.Mac, MySpace, YouTube, Google, BlogSpot, Yahoo, Wikipedia, ...)
- But Still Somebody has to Take Responsibility for Organization, Version Control, ...

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## VI Organization



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## Data Exchange

- **Security**
  - Cost Factor! (e.g. CFBL)
- **Data Exchange Agreements**
  - NATO Policy Necessary
  - Multinational (e.g. MNE 4)
  - National
- **Intellectual Property**
  - Commercial Interests

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## SA-053 Results

- **Support HFM-138**
  - Experiment Setup
- **Support SAS-050**
  - Discussion of Follow on Work
- **Input to RTA VI Setup**
  - Use of WISE Portal
  - Input to VI Meeting
- **Input to RTB Strategic Plan**

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## Lessons Identified

- **Study Team**
  - Commitment of People is not Enough --  
Budget must be Provided Too
  - Change of Team Members Cost Time
- **Dealing with Fast Moving Technology**
  - RTB Procedures don't Fit for Rapid Development
  - Budgeting Process in NATO doesn't Fit Either
- **Provision/Share of Knowledge Critical  
(Data Exchange Agreements, Classification)**

➡ **NATO Not Ready for VI yet ?**

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## Recommendations

- **SAS RSG – Setup and Administration of HBR  
VI in cooperation with RTA IS**
- **HFM RSG – HBR Team and Organization  
Ontology Development**
- **HFM RSG – Multinational Experiment HFM-  
138 Follow On**
- **HFM/SAS RSG – Adopt Existing Technology  
in Developing Podcast Lecture Series for RTA**
- **SAS RSG – Data Exchange Practises in NATO**
- **HFM RSG – The Use of Virtual Worlds for  
NATO R&D in HBR**

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# SAS-053 Questions?

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## Chapter 1 – INTRODUCTION

Research and Technology (R&T) plays a major role in NATO in building capabilities that are required to fulfill NATO's mission. In the past the main objective of R&T was to build more effective weapon systems and to enhance command, control and communications.

Since the end of the cold war experience has shown that conflict resolution requires the application of all elements of national and international power – political, diplomatic, economic, financial, informational, social, and commercial, as well as military. To resolve conflicts or crises, the North Atlantic Treaty Organisation (NATO) adopted a Comprehensive Approach that enables the collaborative engagement of all requisite civil and military elements of international power to end hostilities, restore order, commence reconstruction, and begin to address a conflict's root causes. NATO provides the military element for a comprehensive approach. Many other national, international, and non-governmental actors can provide the civilian elements. In this environment the focus of R&T has to change to include more “soft” sciences like social sciences, economics, psychology, etc. Especially Human Behaviour Representation (HBR) plays an important role in today's scenarios with opposing, neutral and friendly actors in a given conflict.

This change has a dramatic impact on the means to conduct R&T. In the past conferences, workshops and meetings served well for the research community and the decision makers to exchange information, to publish research reports and to remain apprised of relevant scientific developments. Technology development has now a much higher rate of change and capabilities are needed that support an effective and efficient collaboration of geographically distributed research teams and the dissemination of research results and other relevant expertise. With the Comprehensive Approach the research community has grown and in many cases multi-disciplinary research is the only way to achieve the desired results.

Such a capability needed could be a Virtual Institute (VI). “Virtual” is defined in the Oxford Concise Dictionary as “not physically existing as such but made [by software] to appear to do so”. “Institute” is defined as “a society or organization for the promotion of science, education, etc.”. Given both definitions a Virtual Institute could be seen as a “non-physical, but nevertheless fully functioning and capable organism promoting the development and use of research and technology”.

The technology to implement such a Virtual Institute is commercially available and has only recently become available at a cost and performance that makes their use efficient and effective for all NATO members. The more challenging part of building a Virtual Institute in a multi-national environment lies in the build-up of the organization of such an entity and the procedures how to operate.

### 1.1 SHORT HISTORY

The NATO Long Term Scientific Study (LTSS/51) on Human Behaviour Representation sponsored by the SAS Panel published a report for the use by NATO and national authorities on the implications of technological developments to military operations over the next ten to fifteen years. An important part of the report is recommendations for research that address/investigate the implications of projected technological developments. The recommendation of highest priority was to establish a NATO RTO study to investigate the feasibility and utility of assembling a Virtual Institute for research on human behaviour modelling (NATO, 2001). The Virtual Institute was envisioned as a NATO resource that would accelerate technology dissemination in specific technology areas that would include development of a web-based clearing house of databases, models and model components and developing standards, and requirements to support multi-national research on human behaviour modelling.

This particular LTSS/51 recommendation was presented to and approved by the SAS Panel, which in turn established the SAS-ET.V exploratory team. The objective of the exploratory team was two-fold. Firstly,

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it had to advise the SAS Panel and, through cooperation with other RTO Panels, the RTO on the technical merit and feasibility of establishing a Virtual Institute within NATO. Secondly, the SAS-ET.V had to advise the SAS Panel and, through cooperation with other RTO Panels, the RTO the feasibility of enabling multi-national research and development in human behaviour modelling by using the virtual institute concept.

USA (Lead Nation), Canada, Germany, Netherlands, United Kingdom, and NATO C3 Agency were participating in the exploratory team. To address the two objectives for the Panel, several different activities were undertaken to assess the feasibility and desirability of the two concepts. Three meetings were held to discuss the technical feasibility of the concepts, to conduct technical interchange and to assess NATO-wide support for the concepts. In addition, team members participated in their individual countries' technical activities related to the two concepts in order to assess their own countries' technical experts' opinions concerning the concepts as well as support for the concepts and commitment to their execution. A final area of endeavour was an ongoing assessment of the technological foundations needed to implement and operate a virtual institute. In brief, the team found support for the concepts; the technologies needed to implement the concepts are available and have been, in many cases, demonstrated; and there is widespread belief that the NATO community would benefit from the virtual institute concept and that human behaviour representation is an appropriate choice for the demonstration of the virtual institute concept.

The exploratory team briefed the SAS Panel, which decided to approve the Research Task Group (RTG) activity SAS-053 "Virtual Institute on Human Behaviour Representation". The scope and goals for the study are:

- Develop a Virtual Institute Concept for NATO:
  - Organizational;
  - Technical;
  - Multi-national Use and Involvement; and
  - Virtual Institute Metrics and Success Criteria.
- Develop a Roadmap for the Development and Use of Virtual Institutes (VI) in NATO.
- Employ Prototype VI on HBR:
  - Assess Utility of VI Concept; and
  - Research on Team, Group, Organization HBR.

The following nations participated in the study:

- USA (Co-Lead);
- NC3A (Co-Lead);
- Canada;
- Germany;
- Netherlands; and
- United Kingdom.

## 1.2 OUTLINE OF THE REPORT

The Executive Summary gives an overview on the study and highlights the most important findings of the study for the decision makers. The introduction shows why the topic "Virtual Institute" is important for NATO and what can be supported in the Research and Technology area with the Virtual Institute concept.

It also highlights the history, which led to the study activity. A short overview on the report concludes the introduction. Chapter 2 summarizes the SAS-053 work, gives an overview on the findings of the study group meetings, highlights the results of meetings with NATO and nations regarding the build up of a VI, shows the contacts with the HBR community and summarizes a meeting at RTA regarding VI. Chapter 3 consists of the State of the Art report on team, group and organizational modelling. After a short introduction the modelling parameters in team, group and organizational modelling are described. Usage and Applications is followed by an analysis on shortfalls. Chapter 4 shows the VI Concept. After an introduction and the definition of a VI the underlying technology will be reviewed. The organization of a VI is developed and discussed. Usage and data exchange in a multi-national environment are examined. The chapter closes with an overview on relevant current projects. Chapter 5 summarizes the results of the study and lessons identified. The report closes with Chapter 6 on recommendations to the SAS Panel regarding follow-on studies.

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## Chapter 2 – SAS-053 WORK

Main instrument in the work of the SAS-053 study group were the study group meetings. These meetings were used to first initiate the work and to discuss with all members the contents of the study and later to present and discuss inputs to the study by the group members and to coordinate the work. Beside the meetings of the study group the co-chairmen and study team members had meetings with NATO and nations. These meetings were intended to introduce decision makers to the work of the study group and to ask for financial support for the build-up of the Virtual Institute for Human Behaviour Representation. A third area of work was the connection to the Human Behaviour Representation Community. BRIMS (Behavior Representation in Modelling and Simulation) and other conferences were used to present the work of the study group and to get feedback from the community. Also a close connection to the Human Factors and Medicine (HFM) Panel was established. A special meeting of the Research and Technology Agency (RTA) on VI was supported.

### 2.1 SAS-053 STUDY GROUP MEETINGS

Five study group meetings were held:

- 1<sup>st</sup> Meeting September 2004 at NATO HQ, BEL;
- 2<sup>nd</sup> Meeting February 2005 in Orlando, USA (co-meeting with SAS-050);
- 3<sup>rd</sup> Meeting October 2005 at NC3A, The Hague, NLD;
- 4<sup>th</sup> Meeting May 2006 at IDA, Alexandria, USA; and
- 5<sup>th</sup> Meeting June 2007 at IABG, Ottobrunn, DEU.

#### 2.1.1 1<sup>st</sup> Meeting September 2004 – NATO HQ, BEL

The first meeting started with the initiation of the study. Mr. Cornelis Bouman (SAS Panel Executive) provided an introduction in RTO and its study work. The participants introduced themselves and gave a short overview on the interest of their nations in the study area and related work underway.

The chairman of the ET.V, Dr. Sheila Banks, presented the ET.V report, the proposed Terms of Reference (TOR) and the Technical Activity Proposal (TAP), which were approved by the group.

The study group discussed links to other RTO study groups. SAS-050 “Exploring new C2 Concepts and Capabilities”, SAS-057 “Information Operations” and the Long Term Scientific Study (LTSS) on Non-Lethal Weapons were identified. Also a link to the HFM Panel was seen to be necessary.

Phil Reed, the head of Information Management and Systems Branch of RTA gave a presentation of RTO Information Management and the NATO Technology Taxonomy Database. The RTO WISE Information Portal was in the status of being transferred from ACT to an own RTA server. SAS-053 decided to use it as a starting point for the VI.

As a start for the work in the HBR area the State-of-the-Art for Team, Group, and Organisational Modelling was discussed.

Main action items of this meeting were establishing links to the identified other study groups, the build of an SAS-053 WISE portal, draft of an VI concept, proposals for an experiment using the VI and input to the work on the state-of-the-art report.

### **2.1.2 2<sup>nd</sup> Meeting February 2005 – Orlando, USA (with SAS-050)**

The 2<sup>nd</sup> meeting was a co-meeting with the SAS-050 study group. Both groups presented their studies and discussed a possible collaboration. Because of the timelines of both studies SAS-050 couldn't participate directly with an experiment in SAS-053 but stated that they are planning for a follow on activity. Nevertheless cultural variables identified in SAS-050 could be used for a setup of an SAS-053 experiment.

The group discussed possible experiments in the HBR area and decided to coordinate with HFM-138 Adaptability in Coalition Teamwork.

The group started with the preparation of the planned briefing for Adm. Bartoli, Deputy ASG Defence.

### **2.1.3 3<sup>rd</sup> Meeting October 2005 – NC3A, The Hague, NLD**

The 3<sup>rd</sup> meeting started with an update on the briefing of Adm. Bartoli and other activities regarding the involvement of NATO and nations in the build-up/funding of a VI. Everybody is very interested but nobody is able to fund the activity.

The WISE portal, which was used by the group, had technical problems after the move to a new server, so that the practical work for the VI was impossible.

The VI concept of operation was discussed with the group and a first draft put together.

Nations presented their input to the state-of-the-art report. The structure and content of the report was discussed.

An update on the planned experiment together with HFM-138 on understanding cultural diversity in teamwork was given and discussed with the group. The VI could be used in this experiment during the set-up of the experiment in sharing and discussing experiment results between the multi-national participants.

### **2.1.4 4<sup>th</sup> Meeting May 2006 – IDA, Alexandria, USA**

The announced functionality of the WISE portal was still not available and some members still had problems to log in. IMC and RTA planned to have a meeting to discuss issues related to a permanent infrastructure to build-up a VI. The group discussed this issue and decided to be represented in the meeting. The group also discussed other means readily available on the internet to be used instead.

The draft VI concept was discussed and further improved.

The State-of-the-Art Report was further discussed and inputs by the nations (comparison of HBR models, work on ontologies) presented. The topic of gaming was discussed and decided to add a section to the report.

The experiment set up was discussed and information on the used software regarding installation given.

### **2.1.5 5<sup>th</sup> Meeting June 2007 – IABG, Ottobrunn, DEU**

The structure and responsibilities for the Final Report were discussed. It was agreed that state-of-the-art report and the report on the VI concept would be part of the Final Report. Both reports were as draft presented and discussed.

A representative from HFM-138 gave an update on the experiments.

The group discussed the topic results and lessons identified of the study and drafted an input for the final report. Recommendations as outcome of the study were proposed and discussed. The group agreed on a prioritized list of recommendations for the final report.

## **2.2 MEETINGS WITH NATO AND NATIONS**

### **2.2.1 Adm. Bartoli**

The aim of the briefing was to inform Adm. Bartoli about the ongoing RTO SAS Panel Research Task Group on a NATO Virtual Institute for Research on Human Behaviour Representation and especially about the resulting short-, medium- and long-term annual costs for NATO if this approach proves to be cost-effective.

The briefing started to ask: Why a VI for NATO? A VI can serve as an essential mechanism for information exchange and collaboration across the NATO nations. It can foster inter RTO Panel research, faster research distribution, reduce duplication of effort and reduce travel times. It is part of the RTO strategic plan and its implementation.

The next question was: Why a VI for HBR? Human behaviour plays a major role in network centric warfare in asymmetric environments and that is the environment NATO is operating in. It helps internally in achieving improved effectiveness in considering cultural, structural and interoperability issues and externally in the context of Effects Based Approach to Operations in assessing opponents, neutrals and friends. Research and development efforts in the HBR area are extremely varied and must therefore incorporate multiple significant bodies of work. Active research groups exist in different areas of the RTO and in the nations.

Based on the answers to the first two questions the objectives of SAS-053 were explained. A major objective is the development of a VI concept for NATO with its technical and organizational aspects. The test of such a VI in the area of HBR is the second main objective. The prototype to be used for this test has to provide functionality like web-based clearinghouse with databases, etc., and a cooperative environment.

Users of such a VI would be in NATO the RTO with its Panels and RTGs, NC3A, NURC, NATO HQs (ACT, ACO, JFC HQ, JWC, JFTC), in the nations' military and research organizations and in the international community scientific and non-governmental organizations.

To build up such a capability NATO infrastructure funding is necessary. Reuse of resources can help in building up the capability. This could include the use of already existing information systems in NATO esp. in RTO (RTO Forum and WISE Portal), the NATO Combined Federated Battle Laboratories Network and the NATO Science, Technology, and Research Network (STARNET). But even if free internet services are used a budget for the organization and the operation of the VI is required. This could be in the short-term (1 – 2 years) 75k \$ for each year to build up an operating VI prototype, in the medium term 150k\$ per year (3 – 5 years) for the technical base and a VI organization to extend the basic services and in the long term for a full VI 250k \$ for the principal VI organization and technical base plus 100k \$ for each project area within the VI.

The main result of this briefing was that the upper NATO management is aware of initiatives regarding human behaviour representation and virtual institute approaches. In the short term no additional money could be expected to support the study. But in the long term hopefully a seed has been planted that this kind of research has to be supported.

## **2.3 CONTACTS WITH THE HUMAN BEHAVIOUR REPRESENTATION COMMUNITY**

Members of SAS-053 held positions on the conference committee for the Behavioral Representational in Modeling and Simulation (BRIMS), which produced many contacts and project meetings and interactions. Members were also represented on various group activities for HFM and other NATO RTG activities.

## **2.4 RTA VI MEETING**

RTA invited in June 2006 to a meeting on VI. RTA, MSCO, RTA Information Management and Systems Branch, an HFM Panel rep and SAS-053 rep were present. Background for the meeting was a RTB initiative to have a “one stop place” for RTA on the Internet. RTA and IT briefed on the status of the WISE portal and future plans. MSCO gave an overview on actual NMSG project building up portals (Pathfinder, SMART, SimResource Library). SAS-053 gave an overview on the findings regarding the build up and organization of a Virtual Institute and answered questions from the audience.

The discussion showed that some R&T projects use already technologies, which are related to the VI concept (e.g. sharing of documents in a common workspace). But it also showed that the different projects are not coordinated with each other and no integrated solution is used. Especially a coordinating VI organization is missing. RTA Information Management and Systems Branch took the lead for organizing technical workshops and a high level R&T Portal meeting.

## Chapter 3 – STATE OF THE ART SUMMARY

The use of the virtual institute in this initial evaluation can address a wide range of issues. On one end, the distribution of human performance data necessary for the development and use of human performance modeling in many areas of military operations, such as mission rehearsal and mission analysis, is a worthwhile virtual institute starting point. Other ideas for the initial virtual institute prototype included current human performance model validation in a multi-national arena and a large multi-national experiment encompassing many aspects of team, group, and organizational modeling. However, the current HBM efforts consist of a hodge-podge of research aimed at providing human behavior in the simulation environment whether that environment be for training, acquisition, command and control, or decision aiding. However developmental appropriate and research necessitated these effort might be, they lack on unifying factor: a vision. Therefore, SAS-053 decided on an approach to develop the virtual institute prototype by using a baseline HBM project within one of the participating nations and expand that HBM baseline to include multiple nations and multiple teams within nations to develop and build experimental data for use in joint command team operations, a highly stressful and human intensive environment. This experimental prototype path allowed our multi-national research team to exploit the institute and its capabilities to more thoroughly determine how culture and other societal measures influence joint military operational performance. This issue is an important research question with practical military implications and applications for the results of the research, but it has not been undertaken to date because of the cause of assembling the requisite international team. The virtual institute is taking the lead in addressing this important issue since it need not bring all of the researchers to one location for them to perform their work; rather, they will be able to remain in their own labs and develop an international joint experimental plan to address the research issue. The experiment is an extension of cultural experiments determined to be of most value to HBR researchers. This multi-national experiment can investigate the impact of culture on teamwork in both national and multi-national venues. The experimentation involves conceptual model development encompassing the impact of culture on joint military operations, extending experimentation methods to include process and outcome measures, and identifying products for national use to improve leader and team performance in multi-cultural environments. A single experimental design can be executed in all the participating nations to build a baseline of responses from homogenous military teams.

Human behavior modeling is the process of developing computable representations of human actions and/or cognition that occur in response to stimuli (both internal and external to the human). Human behavior models require, as a basis, an accurate portrayal of the modeled users' knowledge and interactions in a process called user modeling. User modeling can be effectively utilized to make explicit the reasoning about the purpose of system adaptations and decisions, to take into account user motivation, and to present a unified model of collaborative, cooperative, and adverse behavior. In addition, employment of a user modeling approach allows the direct incorporation of knowledge derived from cognitive task analysis techniques into the knowledge processing structure of the user model. The main objective of user modeling is to determine what the user intends to do within an environment. Nuten defines human (user) intent as "mental states that drive actions" or actions a user intends to perform in pursuit of a goal state. Brown states an approach to predicting user intent is to identify the salient characteristics of the domain environment and specifically determine the goals a user is trying to achieve. This approach is based on the belief that what a user intends to do in an environment is the result of environmental events occurring in the environment, and by the goals he/she is trying to obtain as a reaction to stimuli. These goals can be explicit or implicit. To achieve a goal, a user must perform certain actions to achieve the goal. Goals can be composed of multiple actions, with many pre- and post-conditions. Pre-conditions include directly observable events in the environment as well as indirectly observable events and cause a user to pursue a goal. Researchers from the fields of artificial intelligence (AI), human-computer interaction (HCI), psychology, education, and others have all investigated ways to construct, maintain, and exploit user models, dating back to at least the early 1980s. This infusion from many disparate research fields has allowed user modeling to focus on the important contributions from

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each of the separate contributing research fields. For example, the user modeling community has been able to reap the benefits from artificial intelligence researchers by various knowledge representations developed by AI researchers such as logic-based techniques, abductive reasoning techniques, semantic networks, machine learning techniques, Bayesian methods, and neural networks.

The most important aspects of developing a human behavior model are *knowledge acquisition*, which is acquiring the information needed to effectively model human behavior within an environment or situation, *knowledge structuring*, which is structuring the knowledge base into a form that can be accessed rapidly and used for analysis and decision-making, and building the *decision-making apparatus* to perform decision (reasoning) in order to simulate human behavior. Knowledge acquisition and knowledge structuring jointly determine the information about the human mental models that is brought to the decision process and the key static and dynamic informational factors in this process. The decision-making apparatus is used to support both near-term, reactive decision-making and long term planning decision-making. Different artificial intelligence techniques, such as case-based reasoning, frames, or fuzzy logic, are typically used in either near-term or long-term decision making to achieve the proper behavior. These three components, knowledge acquisition, knowledge structuring, and decision-making apparatus, are all the subject of human behavior modeling experiments. To be useful, a human behavior model must perform the following:

- 1) Correctly compute outputs of the human decision making process at human-scale rate of time;
- 2) Be unpredictable; and
- 3) Be certifiable.

The first component, correct outputs modeling, forces the HBM to react at a human-scale rate of time and requires that the decisions appear to be made by a human. That is, random, disjointed sequences of decisions, decisions that seem to be made irregardless of the world state, and decisions that seem to be made in total disregard for the success of the mission should not occur. The second component of human behavior, unpredictability, addresses the observation that humans tend to behave in a manner such that human opponents cannot detect patterns in behavior. However, unpredictability does not mean that the behavior is random. Rather, this requirement means that the behavior should be as rich and varied as a human's behavior. The third component of human behavior modeling is that the behavior be certifiable. To be certified, a software system must be able to be measured against and compared to the exhibited behaviors of a human in a comparable situation. Certifiability does not mean that the system is probably correct or that its responses are credible in all situations.

When building a human behavior model, four characteristics are key. The human behavior model should be usable, robust, flexible, and possess the ability to integrate learning and self-explanatory capabilities. A usable model is one that is easily learned and manipulated by the model user for model set-up, modification, and building. A robust model responds appropriately to unplanned and unexpected events with a mechanism that allows for situation assessment, problem solving, and planning, and provides for graceful degradation of model capabilities. A flexible model is one that will allow the incorporation of doctrine, tactical, and knowledge changes in a manner that produces behaviors that are appropriate within the simulation context but not outwardly predictable. Finally, a model that possesses a self-explanatory capability has behaviors that are easily marked within the software when they are invoked and the explanation of the conditions leading to the invocation of the behavior, the behavior action, and the consequences of the behavior are easily traceable, given an appropriate set of software tools. Experimentation, in terms of numbers of subjects, variety of subjects, and repetitions of the experiment, is crucial for developing these four desired characteristics for a human behavior model. The VI offers a means for achieving the breadth, scope, and variability required in order to construct human behavior models. These issues and concerns pertain to the development of team, group, and cultural behavioral models.

The multi-national research experiment that serves as the demonstration vehicle for the prototype VI/HBR must investigate the impact of culture on teamwork in both national and multi-national venues. The experimentation involves conceptual model development encompassing the impact of culture on joint military operations, extending experimentation methods to include process and outcome measures, and identifying products for national use to improve leader and team performance in multi-cultural environments. This experimentation will be executed using a research testbed built around a commercial off the shelf (COTS) computer game, *Neverwinter Nights™*, which is an inexpensive, standardized, research instrument able to explore basic research questions concerning teamwork skills, situation awareness, decision making, task effectiveness, adaptability, and the impacts of personality and cultural traits on these issues. A single experimental design will be executed in all the participating nations to build a baseline of responses from homogenous military teams. Then, that design will be executed with heterogeneous teams comprised of military officers from various nations participating in the baseline experimentation.

The HBR Virtual Institute experiment team collaborated with two NATO RTO groups to further its experimental planning: RTG SAS-050 and an HFM Exploratory Team. The VI/HBR experiment team utilized the main research product of SAS-050, which was a conceptual model of Command and Control (C2). The NATO VI/HBR experiment team analyzed and applied this conceptual model and taxonomy of C2 variables as a starting point for the variables within the cultural modeling testbed to measure for their effects on teamwork and cultural influences to teamwork and leadership. In cooperation with an HFM Exploratory Team, SAS-053 collaborated on the experimental approach to test leader and team adaptability in multi-national coalitions for baseline testing, measurement, and analysis. This experimental plan and approach allows the VI/HBR prototype and the testing results to be utilized in two important ways:

- 1) The results may be replicated and validated through additional work outside the current multi-national research groups; and
- 2) The experimental process may be used to implement additional national research that will be of comparable use across nations by incorporating the experimental and testing process enabled by the virtual institute prototype.

The experiment will also demonstrate the utility and efficiency to be gained by using a virtual institute and its infrastructure to conduct experiments.

### **3.1 HUMAN BEHAVIOR MODELING BACKGROUND**

Human behavior modeling is the development of computable models of human responses to situations that are realistic, believable, flexible, responsive, and operate at an interactive rate. The quality of the human behavior model directly affects the fidelity of the environment. Human behavior modeling is not a simple or straightforward task as it requires the acquisition of both the domain-specific knowledge and the domain independent knowledge that humans use in problem solving. As the basis for selecting the parameters for human behavior modeling, is important to remember that the behavior models must reflect each nation's characteristics. Many nations have undertaken the task of building a variety of models for use by computer-generated actors that reflect their own national behaviors. The development of these models, their variants, challenges, and technological challenges to be overcome can be addressed in the VI. When modeling individual human behaviors, there are a large number of parameters and factors to be considered and portrayed. Individual user models are knowledge representations to depict users' knowledge and interactions with a computer system. The main purpose of user modeling is to determine what the user intends to do within a system's environment for the purpose of assisting the user. In this context, human (user) intent may be defined as "mental states" that drive actions. Intent modeling is based on the belief that what a user intends to do in an environment is the result of events occurring in the environment and the goals he/she is trying to obtain as a reaction to stimuli. These goals can be explicit or implicit, physical or cognitive. To achieve a goal, a user must perform certain actions. Goals can be composed of multiple actions, with many pre- and post-conditions. Pre-conditions include directly

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observable events in the environment as well as indirectly observable events that cause a user to pursue a goal. User models are particularly useful in domains with a heterogeneous group of users and where the system may exhibit flexibility in its “response” to users.

Human behavior modeling also benefits from researchers in the fields of artificial intelligence (AI), human-computer interaction (HCI), psychology, education, and others as they have all investigated ways to construct, maintain, and exploit user models. This infusion from many disparate research fields has allowed user modeling to advance by exploiting contributions from each of the separate contributing research fields. For example, the user modeling community has been able to reap the benefits of AI research by using various AI knowledge representations such as logic-based techniques, abductive reasoning techniques, machine learning techniques, Bayesian methods, and neural networks. The HCI research field’s impact on user modeling can be seen in the use of user models to customize presentation of information to provide feedback to users about their knowledge in a domain and to help users locate useful information. Another HCI impact is to employ lessons learned from user modeling to impact the way we view interactive human-computer environments. This approach proposes examining interactive HCI environments along three orthogonal dimensions:

- 1) Elements – the goals, plans, resources, and actions composing the atomic entities an agent (human or otherwise) is concerned with;
- 2) Processes – the types of processing (e.g. reaction, deciding, learning) that takes place; and
- 3) Relationships – the way agents interact with one another.

This approach makes explicit the reasoning about the purpose of adaptations (why adapt?), treats human and computer agents the same in the environment, takes into account user motivation, emotions, and moods, and presents a unified model of collaborative, cooperative, and adverse behavior. Additionally, user models have taken into account a user’s psychological ability, such as working memory or cognitive load, to adapt a user interface and/or the information presented to the user.

The two user models of primary interest in the military HBM community, behavioral and cognitive models, are both performance models in that they are used to determine a user’s future actions. The primary difference between the two models lies in the level to which the user is modeled. Both models observe the user’s execution of actions; however, cognitive models then attempt to determine the user’s goals, whereas the behavioral model directly forecasts user activity. Human cognitive models have been studied by researchers in the field of psychology for many years. Cognitive psychology is concerned with understanding tasks in which a stimulus is processed in some way before a response is chosen. Humans form cognitive models of their environment to make sense of and organize the information they observe. Cognitive models represent aspects of users’ understanding, knowledge, intentions and processing, and tend to have a computational flavor. Stokes emphasizes that to be adaptive, the system requires a model of the cognitive state of the human operator that will infer both the present level of operator performance and the current state of mental workload and resource allocation. A behavioral model is the other performance type of user model and attempts to address some of the difficulties encountered when using cognitive user model. In a behavioral model, the behavior of a system is manifested in input-output relationships; the user’s behavior can be defined as a succession of states. Put another way, a behavioral model represents the human user as a collection of sequences of actions that the user performs. This model observes and predicts the motions of the user. The system does not attempt to determine the user’s goal, as done with a cognitive model, but directly predicts future user actions based on the status of the environment and past user actions.

The first step in the development of a user model involves examining the tasks users perform and the knowledge they use to perform these tasks and then representing the knowledge. One approach, cognitive task analysis (CTA), centers on informing the design process through the application of cognitive theories. A task is defined as what the person or other intelligent agent has to do (or believes is necessary)

to accomplish a goal by use of some device. Hierarchical task analysis is concerned with establishing an accurate description of the steps that are required to complete a task, the focus of CTA is on techniques that capture some representation of the knowledge that people have, or that they need to have, to complete the task. The underlying assumption of much of cognitive psychology is that a human perceives the world and produces some representation of it in his or her mind, called the “problem space”. This representation is what we would usually call “knowledge”. This knowledge may be described in terms of the concepts that we possess, the relationships between those concepts and our capacity to make use of those concepts. The human then manipulates that representation and produces some output, or behavior, that can be observed. The two principle levels of cognitive activity that must be undertaken within a user centered design framework are the task-action representations and mappings and the goal-task representations and mappings. Of the various cognitive models, the most important historically is the model human processor (MHP), which assumes that a psychological model consists of three interacting systems: the perceptual, motor, and cognitive systems. Each of these systems has its own memory (maintains an internal representation or knowledge) and processor. This model led to the GOMS (Goals, Operations, Methods, and Selection rules) method of CTA. Johnson’s theory of Task Knowledge Structures (TKS) assumes that as people learn and perform tasks, they develop knowledge structures. He utilizes method known as Knowledge Analysis of Tasks (KAT) to identify the elements of knowledge represented in a task knowledge structure. Other cognitive task analysis techniques that focus on different aspects of the general information processing model include the Task Action Grammar (TAG), which is concerned with an evaluation of the learnability of systems; and Moran’s External Task Internal Task (ETIT) and Payne’s Yoked State Space (YSS), which are concerned with the mapping of tasks from the external task space to the internal task space. The papers by Rosenbloom, and Tambe present a brief overview of capabilities for the TacAir-SOAR system. Based on the SOAR architecture, the system capabilities include a knowledge base for the air combat domain, improvements in its behavior, and infrastructure enhancements from the architectural basis. Improvements in the TacAir-SOAR domain capabilities focused on improving the robustness and range of scenarios it can operate within and increasing the number of TacAir-SOAR entities within the DVE. Robustness and range of capabilities were improved via the addition of rules to permit participation in a wider number of missions and the capability to interact with three other aircraft. The authors note that the most significant advance in the system’s capabilities was the addition of the ability to maintain episodic memories of engagements and to use these memories to explain its actions.

These representations of cognitive activity rely upon reasoning systems to supply the decision-making system required to portray human behavior. There are a number of systems that can be used as reasoning systems. Propositional logic assists this reasoning by providing a mechanism that enables us first to evaluate simple statements and, subsequently, complex statements formed through the use of propositional connectives, like *and* and *or*. This mechanism determines the truth of a statement from the truth-values assigned to the original simple statements. Predicate logic is an extension of propositional logic that allows more flexibility and power in the representation of knowledge. Predicate logic permits the expression of relationships between objects or abstract quantities. Predicates are these relationships, and their arguments are the objects that these relationships tie together. Predicate logic also supports the use of variables, which bind a predicate’s arguments to successively different values. Rules represent conditional knowledge that is similar to the way human express it. Rules express knowledge as a two-part relationship. The first part is a conditional test, called the *IF*, the *premise*, or the *antecedent*. If the test is satisfied through a true match with known facts, then the second part, called the *THEN*, the *actions*, or the *consequent*, is executed. Rules look like conditional statements in conventional languages, but unlike the latter, rules are applied in a totally different manner, making rule-based systems declarative. Rules are by far the most popular knowledge representation technique within existing systems. This use can be attributed to the excellent ability of rules to represent heuristic knowledge and ease of implementation and understandability. A semantic or associative network is a labeled, directed graph. The nodes in the network are used to represent various concepts or objects, and the arcs or links connecting the nodes represent the various relationships or associations that hold between the concepts. The important feature of the associative network is the associative links that connect the various nodes within the network and

define associative graphs apart from simple directed graphs. These links define relationships that provide the structure for understanding the meaning represented to define a particular concept and provide a cohesive structure for interpreting the structure and inferring new facts. By representing knowledge explicitly within an associative network, a system obtains a higher level of understanding for the actions, causes, and events that occur within the domain. Associative networks, rules, and logic do not provide the ability to group facts into associated clusters or to associate relevant procedural knowledge with some fact or group of facts. Frames attempt to account for the human ability to deal with new situations by using existing knowledge of previous events, concepts, and situations. A frame provides the structure or framework for representing the knowledge acquired through previous experience. Using a collection of knowledge consisting of a frame name and a set of attribute-value pairs, a frame represents a stereotypical situation from the world. The attributes of the attribute-value pair are often called slots while the values are called fillers. The fillers can additionally be subdivided into facets, each having their own associated values. Unlike frames, the object approach creates a tight bond between the code and data rather than separating them into two complex, separate structures. Small chunks of code and data are tightly coupled together with each of these chunks loosely tied to each other.

While there exist many mechanisms to manipulate knowledge representation techniques, the only ones in current operational use within the simulation community are techniques dealing with logic and rules. Propositional logic and predicate logic both serve as an implementation of automated reasoning. Logic defines sound rules of inference that allow the logical inference of new truths from existing truths. The most significant of these rules of inference are *modus ponens*, *modus tollens*, and *resolution*. Modus ponens forms the basis for deductive reasoning, which is reasoning from known facts to unknowns. Deduction always guarantees a true conclusion if the initial facts or premises are true. Deduction is the most widely accepted as well as recognized reasoning method. Another method of logic reasoning is called abduction. Abduction attempts to derive a rule's premises from observing its conclusions. A final example of logic reasoning is called induction, which forms the basis for learning. Induction is performed by observing facts and generalizing from them. Rules are applied in two ways: data driven and goal driven. If the number of inputs is limited, many inputs are acquired automatically, and/or the number of possible conclusions is large, then rules are applied in a data-driven fashion. Alternately, if the number of possible final conclusions (called goals) is limited, and/or input values are not acquired automatically, then reasoning backwards from a goal is more efficient. In goal-driven reasoning, or backward chaining, the rules are applied only to derive values for goals or for intermediate facts used later to set values to these goals.

## 3.2 HUMAN BEHAVIOR MODELING PARAMETERS

### 3.2.1 Parameters for Individual Modeling

The area of individual human behavior modeling has witnessed a wide variety of approaches. In general, researchers advocate that a model of human behavior should account for attention, intent, situation assessment, decision-making, skills, training, fatigue, environmental stressors, education, experience, and motivations. To date, very few systems have attempted to model more than a few of these factors and most models are generally assembled using an ad hoc approach instead of employing a strong methodology. For example, human behavior has been modeled by separating it into perception, cognition, and action as well as a hierarchy of task flows and cognition. Early efforts at human behavior modeling used finite state machines; recently, these efforts have been coupled with agents to try to improve the fidelity of the modeled behaviors. Concurrent control and cognition in conjunction with arbitration as well as case-based reasoning coupled with machine learning have also been investigated. Intelligent agents have also been used to model behavior by having one agent responsible for each type of behavior and then arbitrating or scaling their individual outputs. Early implementations generally relied upon a blackboard approach to model cognition. Recently, neural networks and fuzzy logic have both been evaluated for their ability to capture and portray a wide range of diverse human behaviors. Recent work in human behavior

modeling for CGAs has addressed situation awareness, teamwork, skill level, training, learning, and psychological factors to a limited degree. Models of the effects of fatigue have been developed, but most of these efforts have been ad hoc and have not produced a methodology or structure for the model. Planning has been modeled as a set of competing processes that gradually progress toward a final solution as additional information becomes available. The cognitive models that have been reported use a variety of techniques such as motivational control, beliefs-desires-intentions, and traits and states. The level of training is modeled by determining the skills relevant to a task and assigning the level of skill given the level of training to be portrayed.

In general, an examination of the human behavior modeling research reveals that the work is fragmented and that research results are difficult to integrate and validate. Currently, there is no comprehensive theory or modeling approach for integrating the various efforts or to serve as a common platform. The results are generally not portable; that is, the software developed for a given architecture cannot be readily migrated to another software platform. The results are also not generally in use; research results have been confined to the laboratory and have not moved into wide use. Finally, the models are difficult, costly, and time consuming to assemble. To improve the fidelity of human behavior models, they must incorporate multiple skill levels, representations of doctrine, and reflect societal, training, and educational differences. Additional behavior moderators such as morale, fatigue, stress, fear, information operations, and intent must be modeled and included within the model.

When attempting to model individuals, a wide variety of parameters must be considered in order to portray a human in a specific situation or set of circumstances. The number of parameters needed to model human behavior, uncertainties concerning the number of parameters that are required, and uncertainties about the interplay between parameters have resulted in a large number of approaches and parameter sets for modeling human behavior. An individual behavior model must account for a number of factors that affect the human's behavior, including skill level representations, stress factor representations, different levels/abilities of performance, and situational psychological aspects. The LaVine, Laughery, Young, and Kehlet taxonomy consists of five skills, which are attention, perception, psychomotor, physical, and cognitive skills. In their model, attention is the ability to attend to a stimulus for extended periods. Perception is the ability to detect and categorize stimuli. The psychomotor skill models the ability to maintain select characteristics of an environment within a desired range of conditions. Physical skill models the ability to perform muscular work. Cognitive skill is the ability to apply concepts and rules to the environment to generate plans and actions. The ability to perform each skill is rated on a seven-point scale by a subject matter expert using the questionnaire. Weaver and Mullen address the subject of modeling military decision-making using a cognitive-type model. Their approach to decision-making modeling is composed of four parts: the intrinsic characteristics of the decision, the perceived environment, a neural network (for decision-making), and three output variables that scale the decision. The two external inputs into the decision are the intrinsic classification characteristics of the decision and the environment for the decision. To characterize the decision these data are then combined using a model of human decision-making implemented in a neural network. Their system has three output variables; the first of the variables is the timeliness of the decision, the second is the quality of the decision, and the third output is the quantitative aspect of the decision.

There are many differences that can be noted in the manner in which individuals and teams perform decision-making, as summarized in Table 3-1. For example, individual decision-making may have a much narrower focus and may not consider all relevant data when compared to team decision-making. Additionally, team decision-making is usually driven by a desire to build a degree of consensus; whereas, individual decision-makers do not have that obstacle. In addition, apparently it is more difficult for a team than an individual to assemble a consistent mental model of the battlespace but teams are more likely to have a broader appreciation for the complexities of the battlespace than an individual's inherent limitations allow them to attain. Experimentation has determined that individuals are limited to being able to accommodate (attend to) seven (plus or minus two) items in mind at any instant. No equivalent formulation that describes a

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team's attention has been developed; but it would seem to be greater due, no doubt, to the ability of the people in the team to overlap and reinforce items to which their individual concerns are addressed (or attended). On the other hand, individuals can readily attend to one item and exclude all other matters from attention; individuals have a well-documented ability to focus their attention on one item to the exclusion of all others. Conversely, it is apparently very difficult for an entire team to focus its attention on one item (and in many circumstances it is counterproductive to do so), providing both the promise that important activities are not overlooked but also threatening to dilute the effectiveness of the actions and decisions of the team. The difference in ability to attend to one matter versus several corresponds to the difference in the number of active decision processes in an individual and a team at any time. Generally, an individual can pursue one active decision process, whereas a team can have several. Interestingly, the literature suggests that both individuals and teams are subject to the problem of process interruption; that is, when a process is underway (whether it is a decision or information flow) and it is interrupted, it is a challenge for the team or individual to recover from the interruption. Though it appears that teams may be able to recover more often than individuals, teams are also subject to more catastrophic failures when interrupted during the execution of a task than are individuals due to the need for communication and a shared understanding of the state of task accomplishment.

**Table 3-1: Individual versus Team Characteristics for Information Management and Decision-Making**

| Characteristic                      | Individual                                                           | Team                                                 |
|-------------------------------------|----------------------------------------------------------------------|------------------------------------------------------|
| Scope of detail                     | Limited, difficult to consider/attend to many details simultaneously | Broad, many details can be considered simultaneously |
| Breadth of attention                | Limited, 7 +/- 2                                                     | Unknown, but seems to scale with size of team        |
| Focus of attention                  | Can be highly focused                                                | Counter-productive to focus on one item              |
| Rapidity of decision-making         | Personality dependant                                                | Team competence and composition dependant            |
| Number of active decision processes | One or few                                                           | Multiple, no generally accepted model                |
| Fatigue                             | One level                                                            | No certain model                                     |
| Decision-making model               | OODA                                                                 | None                                                 |
| Decision-process interruption       | Problem                                                              | Problem                                              |

In general, an individual has one skill level and has one fatigue level at a given time and they change relatively slowly. As a result, it is possible to characterize a person's response to events and potentially determine how to improve individual performance when fatigued, under stress, or when performance does not meet expectations. On the other hand, a team has multiple skill levels in effect concurrently as well as multiple fatigue factors and it is not clear how to combine them or ameliorate their effects in order to improve team performance. Finally, an individual remains relatively "constant" in their performance over the duration of an experiment, a team does not appear to remain "constant" since the team can vary (in composition and therefore "skill" and "performance", as well as in group dynamic and teamwork) over the duration of a simulation experiment.

### 3.2.2 Parameters for Team Modeling and Group Modeling

As the basis for selecting parameters for team and group modeling, is important that the representation of individual nations in a simulation environment reflect each nation's characteristics. Many nations have undertaken the task of building a variety of models for use by computer generated actors that reflect their own national behaviors. The development of these models, their variants, challenges, and technological challenges to be overcome can be addressed in the VI.

In the ITEMS (Interactive Tactical Environment Management System) system described by Siksik, models systems and intelligence for actors within an environment and was designed to simulate Army company-level activities within a battle space. The ITEMS approach to achieving realistic behavior is the use of expert system technology to provide the foundation for a CGA's intelligence. In ITEMS, actors are assembled from libraries that specify sensors, weapons, communications, dynamics, and knowledge. To perform decision-making, ITEMS uses rule-based expert systems and frames and divides the decision process into four types:

- 1) Mission;
- 2) Opponent selection;
- 3) Player action; and
- 4) Command and control.

The player action component contains the knowledge needed to allow the CGA to perform its mission and to react to opponents and external stimuli, and can be specialized into air combat, company, and battalion knowledge bases. Within ITEMS, knowledge is encapsulated in frames, with each frame responsible for representing facts about a specific type of knowledge. To reduce the knowledge representation problem, inheritance is used to permit specialization of knowledge from a frame that represents general knowledge. In the ITEMS expert system approach, there are three separate knowledge representations:

- 1) A database;
- 2) A rules database; and
- 3) A common database.

The object-oriented database holds all of the information required to represent a scenario and it holds the rules database. The scenario definition portion of the database holds modular, frame-based libraries organized in a hierarchical structure that supports re-use of libraries at any level of the hierarchy. Each library is responsible for representing a single type of knowledge/information needed to define a scenario. The rules portion of the database is also structured as re-usable frame-based libraries. Each of the rules libraries is responsible for representing the complete set of knowledge needed to support decision-making for motion, navigation, communication, tactics, and mission execution. Each library is, in turn, composed of frame-based records that contain all of the information needed to make a specific type of decision. Each record is, in turn, composed of rules and state descriptions. The database holds transient knowledge concerning the state of the simulation environment. The ITEMS project devoted considerable effort to the modelling of command and control structure in the belief that correct modelling of command and control would lead to realistic behaviors on the part of the CGAs that it controls. The ITEMS approach seems more oriented toward instantiation of formations, such as companies and battalions, than of individual actors. This system provides the basis for the parameter set developed within SAS-053. ITEMS point towards a number of team performance factors.

When examining and assessing team performance, a number of factors related to both the individuals on the team as well as the team entire must be simulated in order to properly model the team; however, it is imperative that the team's effectiveness be expressed in relationship to each of its goals and not in the aggregate. The individual parameters were discussed in the preceding sub-section, at this point we will

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limit the discussion to team specific factors. The team's situation awareness and its perceptions must be modeled along with the team's ability to work together. Because the team's ability to work together is an important modeling parameter, the effect of cultural diversity upon team performance is important and should be explicitly modeled, which indicates that a framework for experimentation and expressing the impact of cultural diversity should be developed (possibly in conjunction with the HFM Panel). Two more factors to be considered and modeled is the affect of individual perception and individual situation awareness upon team perception and team situation awareness and how these factors affect team performance. When conducting team performance experiments further factors need to be measured and modeled in order to assess the team, and each of these factors must be varied for each individual in the team in order to determine all of the variations in team behavior. These factors include the average data volume to an individual at each point in the team's activity operational scenario, the peak data volume to an individual during the scenario, the data accuracy to an individual, the average taskload to an individual during "normal" conditions in the team's operation, and the peak taskload to an individual during "normal" conditions. Additional considerations include the average taskload to an individual during "stress" or "attack" conditions, the peak taskload to an individual during "stress" or "attack" conditions on the team, the average number of personal contacts/communications outside of team during "normal" conditions, and the average number of personal contacts/communications outside of the team during "stress" or "attack" conditions. Also, for each person in the team the degree of responsibility/autonomy for the individual, the level of situation awareness required by the individual in order to properly perform their team duties, and the degree of autonomy that each individual possesses during different scenarios and during different phases of the scenario must be assessed and modeled in order to simulate the team's operation. Team cohesion also affects team performance and must be assessed in order to build a team model, and if the model is to have high utility, and to accurately model cohesion and team performance, the fidelity and parameters for individuals and sub-groups must be varied in order to assess the entire spectrum of team behaviors. All of these factors come together in a command post setting and affects the effectiveness of the command post's operation. Team cohesion also affects team performance and must be assessed in order to build a team model, and if the model is to have high utility the fidelity and parameters for individuals and sub-groups must be varied in order to assess the entire spectrum of team behaviors.

Command posts are one of the most important areas for team modeling because of their centrality to mission accomplishment and, of course, command and control. Within the design of command post experiments there are four factors that affect command post team performance:

- 1) Sensors;
- 2) Intelligence reports;
- 3) Network/communications devices; and
- 4) Personnel who make decisions, and take actions.

All four factors are nearly independent. There appears to be an inter-dependence between intelligence reporting and personnel decision-making in command post team performance. The research literature and analysis indicates that there are two broad areas of command post team evaluation that must be examined experimentally. The **first** experimental area is the investigation of the four factors separately. The **second** experimental area is examination of the interconnection between intelligence and personnel decisions and actions. Fortunately, the two areas are independent enough so that they can be examined simultaneously; i.e. one experiment can test hypotheses for both areas simultaneously without corrupting the experiment results for either area. When attempting to gain insight into the first area, experiments must be performed to determine how to improve each of the four factors that affect command post team performance. When attempting to gain insight into the second area, experiments must be performed to determine how to improve the processes for gathering, handling, examining, and managing intelligence that affect command post team performance. In sum, command post team simulation experiments should do the following:

- 1) Concentrate on these two cases;
- 2) Assess the flow, quality, and quantity of information;
- 3) Attempt to match real-world command post team expertise, numbers, and taskload, especially in the areas of command post performance that are central to the experiment; and
- 4) Attempt to match the equipment available in the command post being simulated.

For both cases, quality of intelligence reporting may be a factor and should be explicitly considered in the experimental design.

The research literature and analysis indicated that within the area of command post team operations dealing with intelligence that there are two distinct cases of intelligence input to consider. The **first** intelligence case revolves around determining how well the command and control structure and process are able to **correlate activities** in the environment that are precursors to events. A mix of intelligence inputs are needed because the experiment is actually trying to determine how well a significant event can be separated from background information (aka noise). False/inaccurate intelligence would be a normal part of that background, so the ability to detect and reject false positives as well as insure that detection of true precursors is determined. The measures of command and control (C2) performance that must be applied in this case are those that assess the command and control (C2) structure's ability to determine the accuracy/validity of the information that it has and how well a given C2 structure and processes supports the information determinations that must be made. The **second intelligence case** revolves around determining how well the command and control structure and process is able to **move information** between the command post components that need the information at any point in time. In this experiment case, the goal is measuring the latency between the time when information becomes available until all portions of the command post structure that need the information have the information.

When considering experimental area one, the metrics used vary depending upon the intelligence case being considered. For intelligence case one in experimental area one, potential metrics include but are not limited to the following:

- 1) Elapsed time;
- 2) Number of participants in the process;
- 3) Number of extraneous participants in the process;
- 4) Number of precursor events that are addressed by the C2 structure;
- 5) Number of alternative explanations for a precursor event that are considered;
- 6) Criteria applied to determine the significance of a precursor event;
- 7) The number of times that the explanation assigned to a precursor event by a given C2 structure is accurate;
- 8) The "difficulty" faced when determining what a precursor event signifies;
- 9) The number of times a sensor is re-tasked correctly;
- 10) The number of times a sensor is re-tasked incorrectly (unnecessarily);
- 11) The "quality" of the decision/interpretation; and
- 12) The overall "quality" of decision process.

For intelligence case two in experimental area one, potential metrics include the following:

- 1) The speed of the movement of information through the command post and C2 structure;

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- 2) The number of people who should have the information but did not get it (directly);
- 3) The number of people who did not need the information but received it;
- 4) The information volume;
- 5) The “quality” of communication;
- 6) The number of times that information has to be retransmitted; and
- 7) The latency between when a re-tasking directive is sent and when the re-tasking is accomplished.

When considering experimental area two, the metrics to be used do not vary depending upon the intelligence case being considered. For this experiment area, potential metrics include but are not limited to the following:

- 1) The elapsed time to make a decision;
- 2) The “quality” of a decision;
- 3) The number of alternative responses considered;
- 4) The “quality” of processes employed;
- 5) The number of people involved in the decision process;
- 6) The number of extraneous participants in the process;
- 7) The criteria applied to determine a response;
- 8) The “difficulty” of determining the correct response;
- 9) The number of pieces of information considered when formulating a response;
- 10) The number of pieces of extraneous information considered when formulating a response;
- 11) The overall assessment of the command post’s “comprehension” of the battlespace; and
- 12) The ability of the command post members to form a common, shared mental model of the battlespace.

### 3.3 EXAMPLE HUMAN BEHAVIOR MODELING APPLICATIONS

# Modeling Effects Based Operations

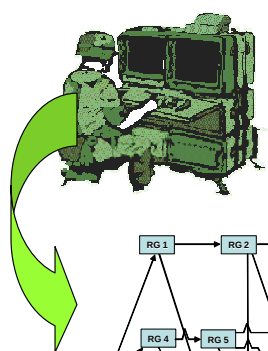
Liz Bowman  
May 11, 2006  
SAS-053 Meeting

# Agenda

- C3TRACE architecture
- Introduction to MNE 4
- MNE 4 Model-Test-Model Development
  - Model: The expected EBAO model
  - Test: Data Collection at MNE 4
  - Model: Model Refinement

2

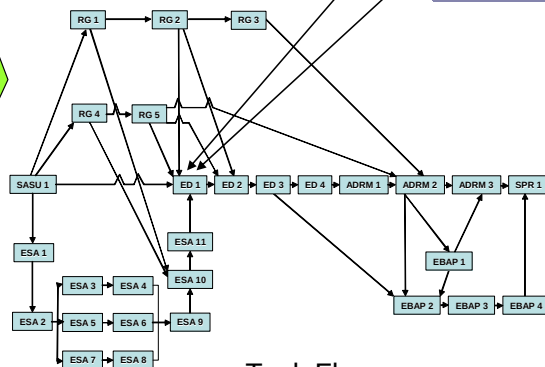
## C3TRACE Components



### Communication Flows and Content Analysis

| Decision                      | Enemy Who | Enemy What | Enemy Where | Enemy When | Friendly Who | Friendly What | Friendly Where | Friendly When | Friendly How |
|-------------------------------|-----------|------------|-------------|------------|--------------|---------------|----------------|---------------|--------------|
| Time Since Update (min)       | 10        | 2          | 10          | 10         | 10           | 10            | 10             | 10            | 0            |
| Frequency Notability Category | D         | D          | A           | A          | D            | D             | A              | A             | D            |
| Decay Rate (% per min)        | 1         | 1          | 5           | 5          | 1            | 1             | 5              | 5             | 1            |
| Info Quality (%)              | 90        | 98         | 50          | 50         | 90           | 90            | 50             | 50            | 100          |
| Average Info Quality (%)      | 74.2      |            |             |            |              |               |                |               |              |

Communication Elements



Task Flows

SA  
1 Perception  
2 Understanding  
3 Projection

- Time for task completion
- Workload (V,C,A,P)
- Assignments of tasks to individuals/groups

## C3TRACE Outputs

- Utilization rates by persons/groups
- Periods of high workload and associated consequences: dropped tasks, delayed communications, missed communications
- Average information quality, based on each communication's:
  - Time since update
  - Volatility of information (enemy who/enemy where)
  - Decay rate of information
  - Original Information quality (complete, timely, accurate)
- Probability of decision quality based on information quality

4

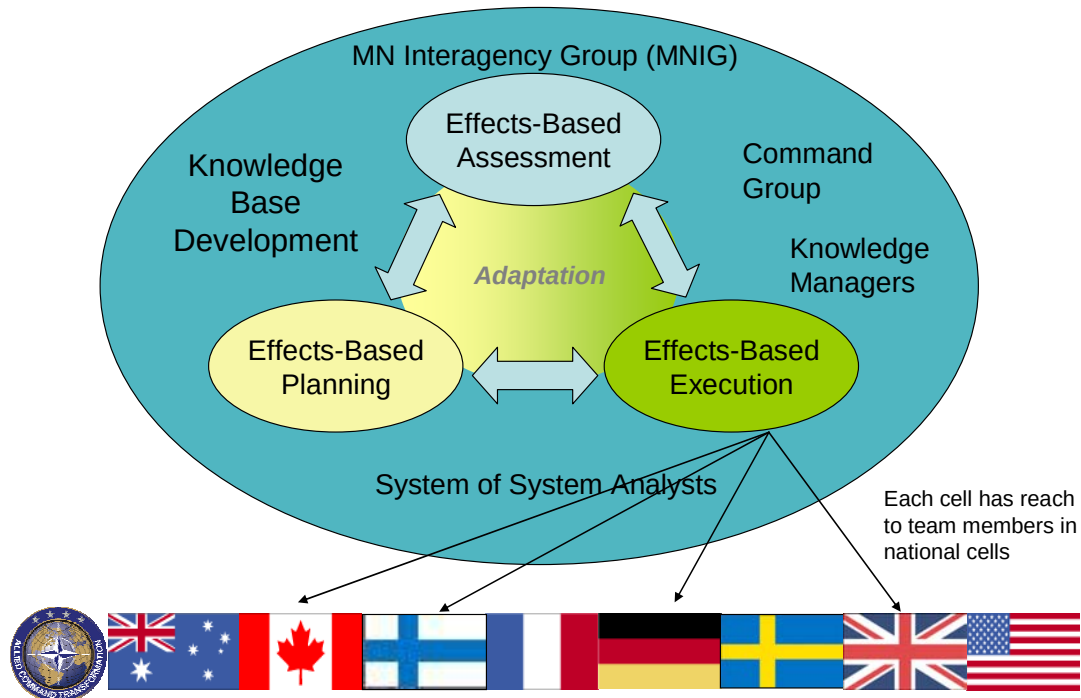
## MNE 4 Review



- Coalition HQ (operational level) conducting a peace support operation [planning, execution, assessment]
- Distributed context: participants used collaborative technology to execute tasks
  - Text chat
  - Audio
  - Limited Face to Face meetings
- Concept of Operations document for MNE 4 defined process and organization required for experiment execution
- Technology used included full-HQ use (IWS) and functional use by groups (EBA used EBAT, EBP used EBTOPFAS)
- MNE 4 was an 8 nation coalition

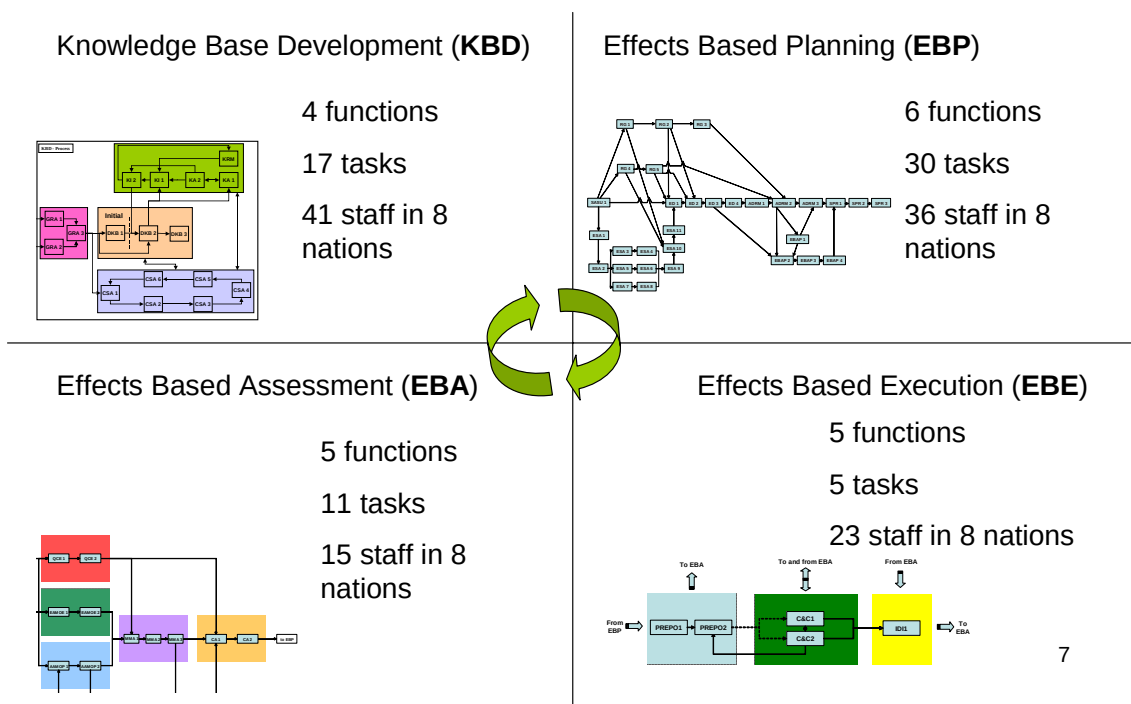


# MNE 4 Organization



## MNE 4 ConOps Review

The ConOps was the basis for the Expected MNE 4 Model



## Communication Events

- High level documents
    - Commander's initial guidance
    - Campaign Assessment Status Report
  - *Generally* produced by EBP and used as inputs to EBE, EBA
  - Communication events were the product of several tasks and triggered another set of tasks
  - Each communication event was weighted according to the scale on the right
- Does the C. E. address:
  - Completeness – Enemy/Friendly
    - Who
    - What
    - When
    - Where
    - Why
    - How
  - Feasibility of resources
    - Time
    - Means
  - Suitability
    - Impact on mission accomplishment
    - Impact on compliance with commander's guidance
    - Impact on compliance with commander's intent
  - Acceptable risk
    - Time, equipment, Soldiers, position losses
  - Flexibility
    - Enemy COA1
    - Enemy COA2
    - Enemy COA3

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## Comments on Expected *a priori* Model

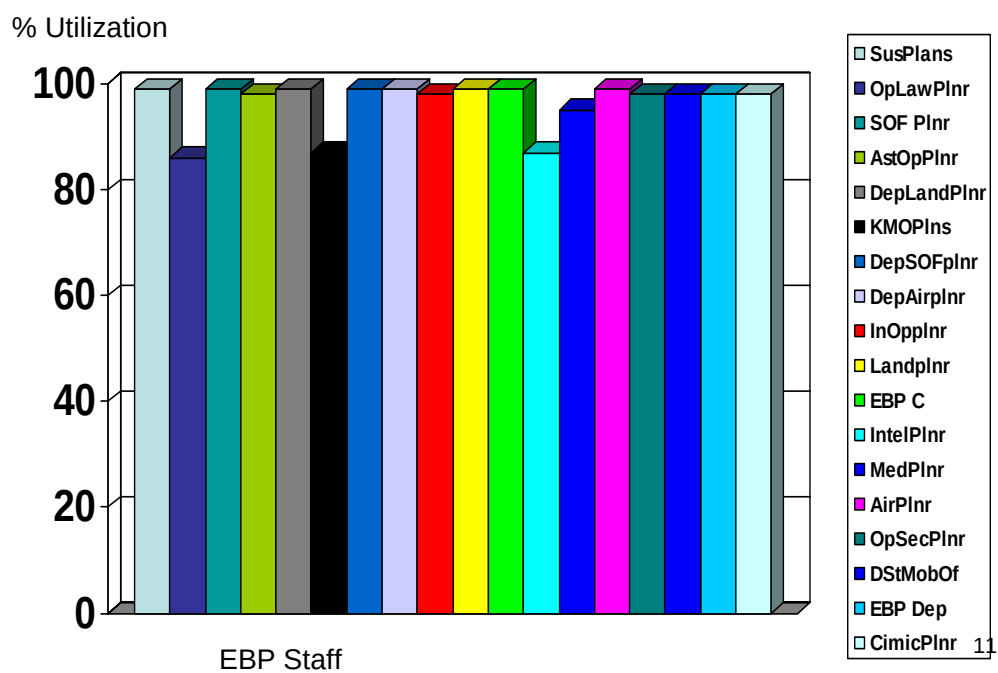
- All inputs (with exception of task times) obtained from ConOps
- As such, the expected model is a test of the ConOps
- ConOps assigned tasks to large groups (planners) vice discrete subsets
- Only EBA Chief was able to assign specific tasks to individuals
- Task times were estimated based on pre-MNE 4 process rehearsal and subject matter expert advice

9

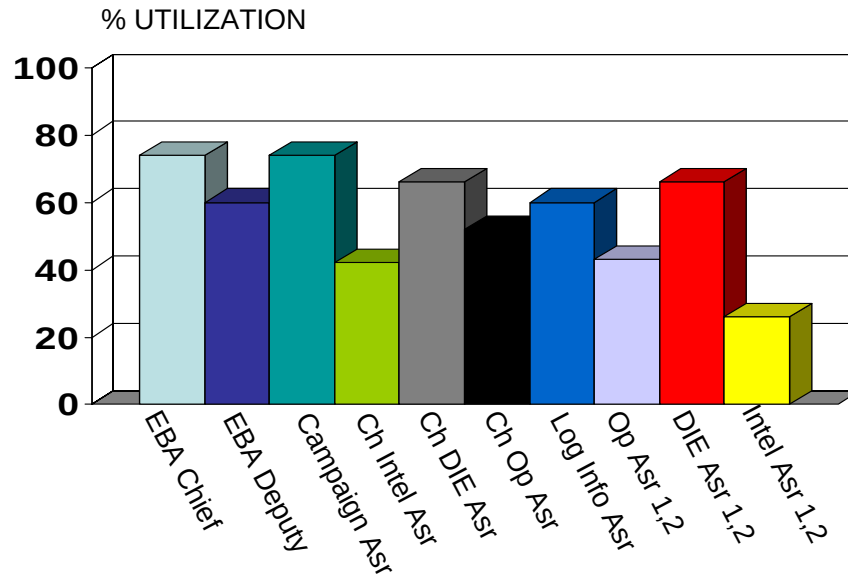
## Model - Test - Model

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### EBP Operator Utilization Rates

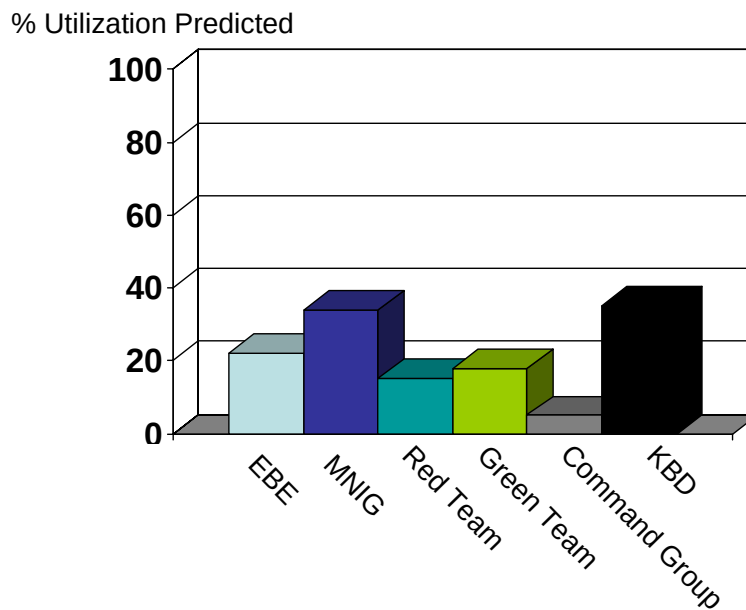


## EBA Operator Utilization Rates



12

## Operator Utilization Rates for Other Groups



13

## Communication Outputs

- C3TRACE default decision quality setting used (100%)
- Probability of making a good decision in expected model ranged from 94% to 100% based on the average information quality of communication events
- Decision quality was rated as “good”
- Cautious interpretation of these results

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## Model - Test - Model

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## Data Collected in MNE 4

- NASA TLX Workload 12 days
- Perception of Information Quality
- Observations of task completion
  - Who participated
  - How was task handled (Large group? Smaller groups?)
  - Task time
  - Communications associated with tasks
  - Delays in processing task and explanations
- Observations of Communication Events
  - When/how communicated (email, voice, text, face)
  - When received (delays?)
- Participant comments on process and organization
  - Were tasks redundant or missing?
  - Were tasks out of sequence?

### • NASA TLX:

- Mental workload
- Physical workload
- Time Pressure felt
- Satisfaction with performance
- Effort
- Frustration

### • Information Quality

- Accurate
- Appropriate
- Access
- Relevant
- Timely
- Complete
- Sufficient
- Concise
- Interpretable
- Understandable

## Data Analysis

- Workload varied by EBAO group
  - Overall Means for each group will be used to adjust operator utilization
- Information quality averaged around 4.2-4.6 for 'characteristic' of message (accurate, appropriate, relevant, timely) but slightly lower (3.8-3.9) for 'function' of message (complete, sufficient, concise)
- Tasks essentially remain unchanged in flow, but larger groups broke into smaller subgroups for efficiency (working in parallel)
- Task times were fairly close to actual in EBP and EBA but not EBE (monitoring operations a continuous activity)

## Model Test Model

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## Refining the Model

- Task assignments will be readjusted to reflect MNE 4
- Information quality will be degraded to match actual data
- Operator utilization will be modified to match reported workload
- Refined model should be completed by September 2006

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## Developing and Comparing HBR-Approaches *continued*

Prof. Dr. Harald Schaub

TO RTO Task Group (SAS-053)

**A Virtual Institute for Research on  
Human Behaviour Representation**

at IDA 10 – 12 Mai 2006



### Modelling Requirements

The “five commands” of HBR modelling are:

1. Models must be derived from real life phenomena, e. g. typical scenarios, real events.
2. Models must have construct validity, i. e. based upon scientific constructs and empirical research findings.
3. Models must have face validity to typical representatives of the real life, from which the models were derived.
4. Models must serve non-trivial analytical and training purposes.
5. Models must be open to validation on the basis of real life data, collected by serious scientific research (No arbitrary “data farming”)
6. The relevance for VI-HBR is to have first and decisive rule set, which enables the user to evaluate the importance of modelling approaches.

### Scientific Paradigms

- Mechanistic engineers minded
- Physical approach
- Biological approach
- Economic resources minded
- Computer sciences minded
- Systems dynamics approach
- Behavioural and social sciences

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### Level of 'behaviour'

- Physiological
  - (nerves and their actions)
- Anthropometrics and biomechanics
  - (main parts/members of the human body and the manipulation of technical parts)
- Individual person
  - (mental actions, actions in the 'outer world')
- Social phenomena
  - (group dynamic actions, team work, inter-personal actions)
- Organisational phenomena
  - (interaction between organisations, individuals and groups)
- Inter-cultural phenomena
  - (interaction between people with highly different cultural backgrounds)

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## General model of action organisation

The phases/different processes of information processing of a General Model are

- goal elaboration
- information gathering
- mental modelling
- prognosis
- planning
- decision making
- acting
- effect control
- (self) reflexion
- (self) modification/adaptation.

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## General model of action organisation

The action levels range from

- Reflex
  - (e. g. eyelid twitch)
- Automatism / skill based behaviour
  - (e. g. acting in panic)
- Trail-and-Error
- Routine / rule based behaviour
  - (e. g. routine manipulations of engines, like driving a car)
- Problem-Solving / Knowledge based behaviour.

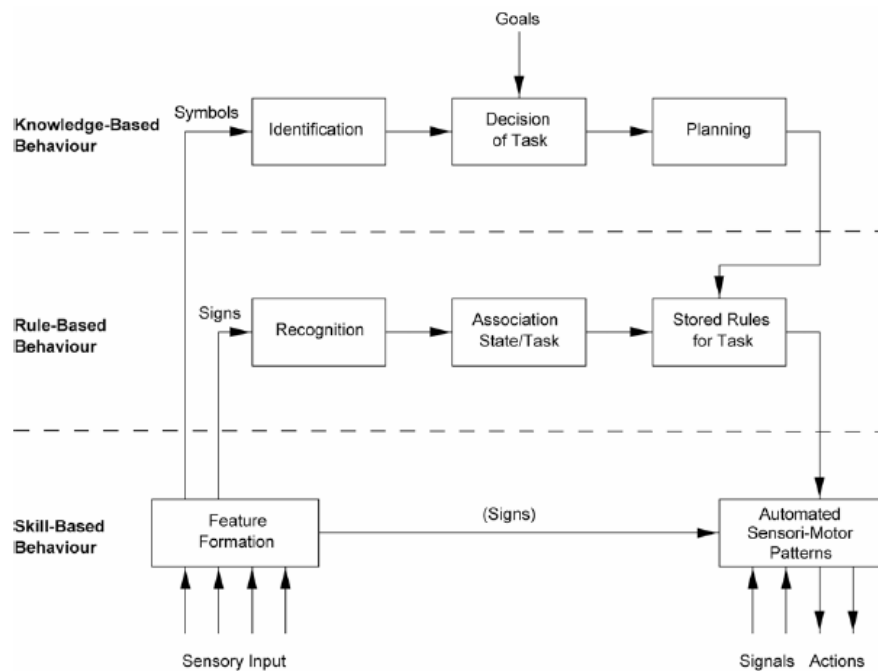
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## Rasmussen Ladder



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## Phenomena/Factors on the task level

- |                            |                                  |
|----------------------------|----------------------------------|
| ■ External task-definition | ■ Complexity                     |
| ■ Attended time            | ■ Agents' Coordination           |
| ■ Efficiency of agents     | ■ External coordination          |
| ■ Efficiency of group      | ■ Agents' Motivation             |
| ■ Influence HK             | ■ requirement/competence fitting |
| ■ Epistemic competence     | ■ Indefiniteness                 |
| ■ Compiling agents         | ■ Variability                    |
| ■ Obstacle                 | ■ Time frame/available time      |
| ■ Expected efficiency      | ■ Perceived efficiency           |
| ■ Heuristic competence     | ■ Time required                  |
| ■ Competence/Expertise     | ■ Pressure of time               |

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## Phenomena/Factors on the individual level

- |                                             |                                           |                                  |
|---------------------------------------------|-------------------------------------------|----------------------------------|
| ■ Intentions                                | ■ Comradeship                             | ■ Ability to regenerate          |
| ■ General education                         | ■ "Knowledge of organisational structure" | ■ Regulation levels              |
| ■ Coverage / Accomplishment of fears        | ■ Cognitive capacities                    | ■ Religion                       |
| ■ Mastery of tasks                          | ■ Ability to communicate                  | ■ Risk awareness                 |
| ■ Education and further education           | ■ Acceptance of complexity                | ■ Routine                        |
| ■ Balance / Stability                       | ■ Stamina                                 | ■ Threshold of pain              |
| ■ Automatism                                | ■ Ability to cope with conflicts          | ■ Education                      |
| ■ Mobility / Flexibility                    | ■ Control                                 | ■ Self-confidence                |
| ■ "Combined-Experiences"                    | ■ Willingness to cooperate                | ■ Desire to win                  |
| ■ Ability to delegate / Ability to deputate | ■ Communication skills                    | ■ Soldierly behaviour            |
| ■ Empathy                                   | ■ Fitness                                 | ■ Language skills                |
| ■ Decisions                                 | ■ Power / Strength                        | ■ Knowledge of strategies        |
| ■ Decision-making ability                   | ■ Creativity                              | ■ Coping with stress             |
| ■ Resoluteness                              | ■ Applied geography                       | ■ Knowledge of tactics           |
| ■ "Epistemic Expertise"                     | ■ Careers                                 | ■ Capacity for teamwork          |
| ■ Pool of experience                        | ■ Productivity                            | ■ Persuasiveness                 |
| ■ Experience concerning success             | ■ Learning aptitude                       | ■ Exposure to pressure of time   |
| ■ Confidence concerning success             | ■ Shortcoming / Insufficiency / Flaw      | ■ Tolerance of Indefiniteness    |
| ■ Ethics and moral                          | ■ Knowledge of human nature               | ■ Impartiality                   |
| ■ Ethnological Experience                   | ■ Military skills                         | ■ Sense of responsibility        |
| ■ Know-how / expertise                      | ■ "Ability to moderate and mediate"       | ■ "Trial and error"              |
| ■ Coping with frustration                   | ■ Ability to motivate                     | ■ Reliability                    |
| ■ Leading-qualities / Talent                | ■ Motives                                 | ■ Perception                     |
| ■ Health                                    | ■ Curiosity                               | ■ Appreciation                   |
| ■ Basic skills                              | ■ Individual characteristics              | ■ Knowledge and cognitive skills |
| ■ Actions                                   | ■ Plans                                   | ■ Targets                        |
| ■ "Heuristic competence"                    | ■ Problem solving                         |                                  |
| ■ Cooperativeness                           | ■ Forecast and expectations               |                                  |
| ■ Hypotheses and models                     | ■ Emotional stability                     |                                  |
| ■ Informations                              | ■ Legal expertise                         |                                  |
| ■ Intelligence                              | ■ Reflexes                                |                                  |
| ■ Intercultural decision making             | ■ Reflection and modification             |                                  |
| ■ "Joint-experiences"                       |                                           |                                  |

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## Phenomena/Factors on the group/team level

- CPS scheme
- Extent of hierarchy
- Fitting of leadership
- Formality of interactions
- "Groupthink."
- Impact of leadership
- Isolation
- Presence of the leader
- Scheme of cooperation
- Ways of leadership

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## Phenomena/Factors on the organization/interagency level

### Within organisations

- Analytical division of labour
- Number of groups
- Eye level contact
- CMC
- Degree of differentiation
- Deployment
- Size of groups
- Command structure/hierarchy
- Information management
- Knowledge of Corporate Culture
- Cohesion
- Organisational division of labour
- Corporate Culture
- Part – organisations
- Virtual elements

### Between organisations

- Analytical work sharing between organizations
- Divergence of organization cultures
- Hierarchy
- Inter-organisationalen contacts on an equal level
- Inter-organizational goals
- Inter-organizational information management
- Knowledge about shared values and norms
- Number of different reporting channels
- Organizational work sharing between organisations
- "Virtual inter-organizational elements"
- Ways of communication
- Ways of cooperation

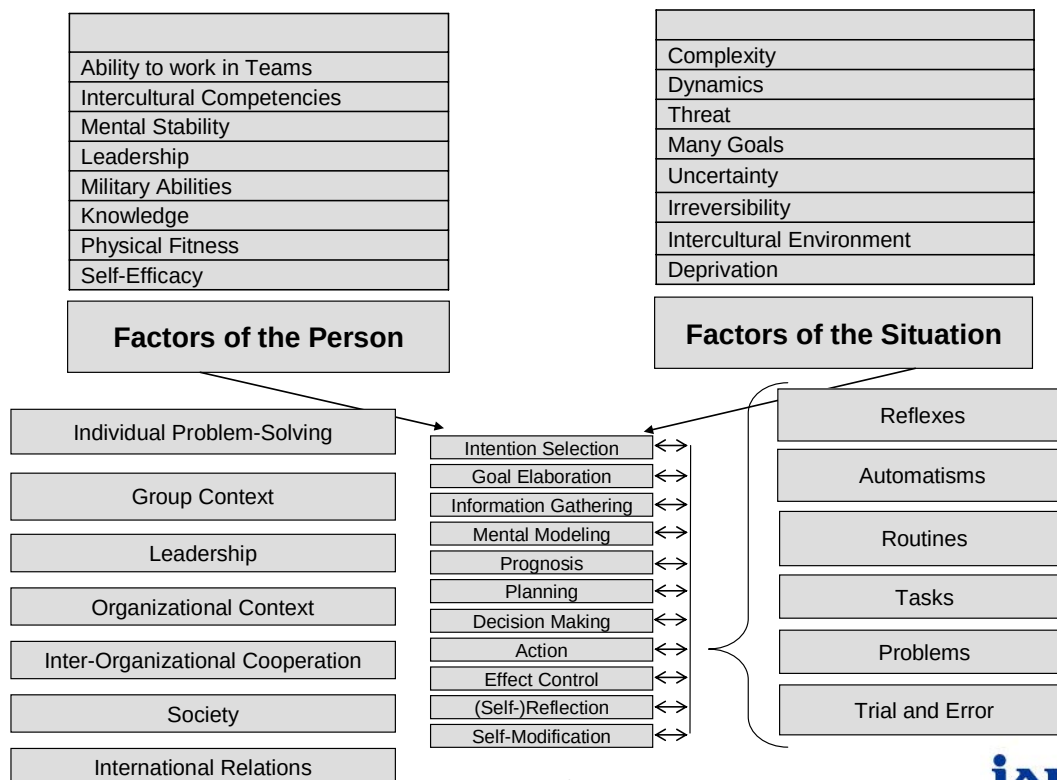
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## General model with some interactions



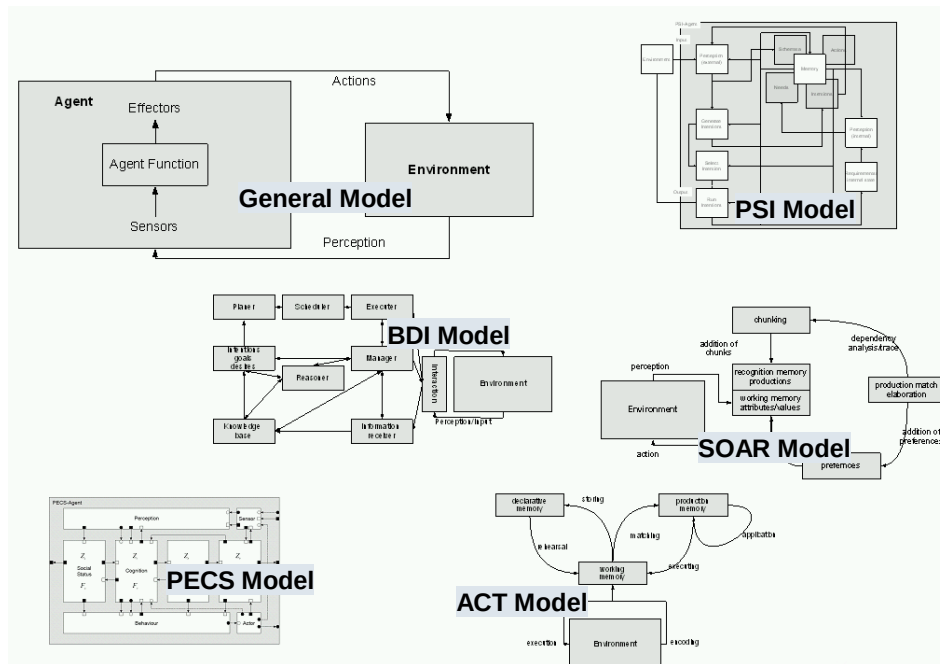
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## Comparing (general) Approaches



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## (Some) of the requirements for the HBR virtual institute (from „Final Report from ET.V for SAS-053 approval”):

- Develop a virtual institute technology development strategy;
- Develop virtual institute metrics and success criteria;
- Develop a virtual institute research plan and strategy;
- Determine the key steps for developing the virtual institute and the key technologies needed by the virtual institute to conduct initial experiments;
- Develop a methodology to assess technical benefits of virtual institute-based experiments and tests as compared to conducting equivalent experiments and tests in one location;
- Develop descriptions of partitions of work between national participants based on capabilities and national interests;
- Develop guidelines for technology sharing among virtual institute participants;
- Identify and prioritize experiments and tests that are of common interest to the participating countries;
- **Develop ontologies for human behaviors;**
- **Develop and employ a methodology that can be used to organize a human behavior model library for each country and for all countries as well as enable the development of common human behavior models and model components;**
- Develop a virtual institute human behavior model experiment plan;
- Determine common behaviors and country specific behaviors via experiments;
- Determine commander behavior modeling techniques;
- Develop a sequence of experiments and tests that will demonstrate benefits and desired level of international cooperation for virtual institute human behavior model development
- Provide capabilities for serving as a clearing house for research results
- Provide a library of research results, ongoing academic research, and experiments
- Insure that HBR studies are coordinated between nations
- Serve as a testbed host for distributed experiments
- Distribute human performance models to organizations that need them
- Serve to foster cross-national academic research support for HBR model development and support validation of models
- **Development/promulgation of standards or measures for human behavior models, developing extensible standards for describing/defining human behavior models, and determining when the conditions/circumstances where each model applies**
- Development of composable HBR data models and development of the means for storing data in a standard manner so that it can be reused across experiments

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## Chapter 4 – VI CONCEPT

### 4.1 INTRODUCTION

The idea of virtual research organizations is driven by economic and security requirements on one hand and by technological progress especially in high-speed digital communications and the semantic web on the other. Advances in technology play a major role for economic growth and security in the information age we are now in. Research and Development (R&D) is an important area, which can't be neglected. Research institutes and how they work together play a major role in this regard. The capability and efficiency of research institutes working in an international network is therefore important. Today's high technology research is furthermore interdisciplinary and requires cooperation of many different research areas, which normally can't be found located in one place. The exchange of information has to keep pace with the accelerating rate of change of technology development and can't rely on the traditional means of publications, conferences and workshops any more. On the other hand information technology has changed ways of communication and opened a global information network. The use of this network is more and more common and the younger generation is used to it in their private life. They expect this kind of communication and information exchange also in their business or research life.

NASA with their Virtual Research Center, which started in 1995, was one of the first, building a virtual research organization. Others followed and the European Union started in 2000 with a program supporting the build up of virtual institutes to enable a better cooperation of research institutes and the industry. NATO RTO started to discuss this topic also in the year 2000. The concept of a Virtual Institute or Laboratory was introduced by Rene Willems (SAS Panel Chair at that time) in the RTB Meeting in September 2000 to NATO. The LTSS on Human Behaviour Representation Study Group discussed this topic also in their meetings and recommended a follow-on study on the Virtual Institute Concept in their Final Report. The SAS Panel approved this recommendation and established an Exploratory Team (ET.V), which developed a program of work for the research study group SAS-053.

As said above NATO R&D depends on the cooperation of the different research entities in NATO (RTO with its Panels and RTGs, NC3A, NURC), in international and national scientific, governmental and non-governmental organizations and in industry. All these entities could be users/members of a virtual research organization.

Potential advantages of the use of virtual institutes are:

- Costs/Economics:
  - Reduce of travel time and cost;
  - Reduce cost per experiment/exercise; and
  - Reduce elapsed time between experiment/exercise conception and execution;
- Cooperation:
  - Reducing duplication of effort;
  - No limitation of size and scale of effort by one institute or even one nation;
  - Improve re-use/exploitation of prior work;
  - Foster inter RTO Panel research; and
  - Improve access to international expertise.

## VI CONCEPT

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- Quality:
  - Better peer review of results; and
  - Bringing in different regional/cultural knowledge.
- Technology and Opportunities:
  - Faster research distribution; and
  - Experience from other studies from internet.
- Security:
  - Better control of access to critical information; and
  - Better protection of secured areas because of limited physical access.

In the following a definition for a virtual institute is given. Underlying technologies and their development and use for the virtual institute are discussed in the next section. Besides technologies and their use the organization of a Virtual Institute plays a major role. A recommended approach is shown in Section 4.4. Section 4.5 deals with the usage of a Virtual Institute in RTO and gives practical examples. Security and intellectual property will have an impact on data exchange in a NATO RTO Virtual Institute. Section 4.6 highlights some issues on this topic. In Section 4.7 you will find a short description of the RTO website.

## 4.2 DEFINITION

The European Commission (EC) defined a Virtual Institute in a press release regarding their Fifth Framework Programme as: “A Virtual Institute links geographically scattered, complimentary research and industrial elements in order to transfer and implement research results rapidly, primarily in industrial applications and services. It can be thought of as a market-oriented network” (see [2]). The intention of the EC was to establish Virtual Institutes as independent and self-financing legal entity, which could provide services to European industry, government and research organizations.

In the research area the concept of Virtual Laboratories was discussed starting in 1996. The term collaboratory was coined when William Wulf merged “collaboration” and “laboratory” to describe a “... center without walls, in which the nation’s researchers can perform their research without regard to geographical location – interacting with colleagues, accessing instrumentation, sharing data and computational resources, and accessing information in digital libraries” (see [4]). In 1999 an Expert Meeting on Virtual Laboratories was held at the International Institute of Theoretical and Applied Physics (IITAP), IOWA State University sponsored by the United Nations Educational, Scientific and Cultural Organization (UNESCO) (see [3]). This meeting came up with following definition of a Virtual Laboratory: “An electronic workspace for distance collaboration and experimentation in research or other creative activity, to generate and deliver results using distributed information and communication technologies”. A major point in this definition is that people at various sites could work together collaboratively and simultaneously having access to a digital library. The experts at the meeting saw three main directions for a Virtual Laboratory:

- Project driven with a well defined goal and a fixed timescale;
- Large and complex projects with interdisciplinary, cross-organizational participation and the sharing of major experimental devices; and
- More general interactions among members of a common specialist community with multi-national collaboration.

The Exploratory Team (ET.V) discussed in its final report the topic why to call it a Virtual Institute and not Laboratory, Testbed or Workshop. Main reason for that was that an institute is a much wider term,

which connects very well with its research orientation. A laboratory, testbed or workshop is normally a part of an institute and sometimes even has a very limited lifespan like a testbed or a Virtual Institute as defined above. Other parts that could be hosted by an institute include a (digital) library, a web-based clearinghouse, an education and training facility (including e-learning) and other digital services. Our definition of a Virtual Institute is:

“A Virtual Institute is a permanent collaborative research environment with its own organization providing support, facilities and tools for research, experiments, collaboration, and distribution of research results.”

An important point in our view is that the Virtual Institute is a permanent entity which has its own attached organization not only to run and maintain all technical facilities and keep it running but also to steer the institute and its development regarding the selection of future research projects, experiments and the further development of collaboration facilities and services like standardisation, training and education and legal issues as intellectual property and security.

### 4.3 UNDERLYING TECHNOLOGY

Core technology to realize a Virtual Institute as a collaborative research environment is Information Technology (IT). IT is a general term that describes any technology that helps to produce, manipulate, store, communicate, and/or disseminate information. For the Virtual Institute concept the communication and dissemination aspect plays a major role to link computer systems, research tools and other communication equipment like video or voice in multiple, geographically distributed locations. This chapter will give an overview on current developments and available tools in this area. A more detailed view can be found in [6].

J. Vary distinguishes between three classes of communication in his taxonomy of Virtual Laboratory tools [3]:

- Person-to-person communication in a network of scientists;
- Person-to-equipment communication to control a network of tools; and
- Person-to-metamachine communication which involves access to an intelligent network of information and computing resources.

For all classes of communications the transfer of digital media over a common network is essential. Digital media includes:

- Text (formatted and unformatted);
- Graphics (pixel or vector oriented);
- Audio;
- Video; and
- Computer programs.

The kind of media and the amount determine the necessary bandwidth for operation. In Europe and North America is in most places a sufficient Internet connection available. If in the case of experiments or other special projects involving subject matter experts or scientists from other nations a connection to other places has to be established (e.g. to an ongoing operation like ISAF) special lines might have to be build up or rented. Also if secure lines are needed it has to be checked if the desired connectivity is available.

The technologies underpinnings needed to implement a virtual institute have only recently become available at a cost and performance that makes their use efficient and effective for all NATO members.

### 4.3.1 Person-to-Person Communication

This class includes all conventional forms of human interaction such as conversation, telephone call, book or report, letter, or TV and their computer-supported analogs voice over IP, video teleconference (VTC), e-mail and the WWW. Table 4-1 shows the division in synchronous and asynchronous communications.

**Table 4-1: Person-to-Person Communication**

| Synchronous                                                                                                             | Asynchronous                                                                            |
|-------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Telephony<br>Chat<br>Whiteboard<br>Video teleconference<br>Virtual awareness<br>Application sharing<br>Shared workspace | E-mail<br>File exchange<br>Internet radio<br>Computer Supported Cooperative Work<br>WWW |

Following tools are widely available:

- Telephone**  
The classic analogue phone is more and more replaced by voice over IP systems. Any computer who is linked to the Internet can be used for phone calls or even audio conferences. The quality of this service over the open Internet is not always high. There is also special equipment available for conference systems.
- Chat**  
Chat is a text based synchronous communication over a computer network (e.g. the Internet). Its demands on bandwidth and quality of service are very low. There are lots of chat-servers installed on the Internet. Chat software comes normally also with office packages like Microsoft Office and allows closed user groups in an office environment.
- Whiteboard**  
A Whiteboard extends the possibilities of a pure text chat system to the exchange of any graphical information. Special systems like for mathematical equations are available. A Whiteboard system could also be used to share the output of a computer program in real-time on the screen with a remote user.
- Video Teleconference (VTC)**  
VTC can run on dedicated lines, ISDN lines or over the Internet and is not very expensive any more. Dedicated lines give a better quality than the Internet but Internet VTC is usable. For Internet VTC a special server is necessary which the Virtual Institute could host or it could be an available server like from Apple me.com or AOL AIM, etc., with a low fee. Very often VTC applications offer also other functions like whiteboard or chat.
- Virtual Awareness**  
Behind virtual awareness is a concept of virtual vicinity. Web users are able to see each other when serving the same web site or any other kind of vicinity defined in the respective server. This would allow starting a synchronous communication with each other. This concept could be used on the Virtual Institute server to facilitate cooperation.
- Application Sharing**  
Systems like Windows Terminal Server or MAC OS X screen sharing allow users to log into a system remotely. This could be very useful during a VTC or an experiment. Also for giving support to other users it could be very helpful.

- **Shared Workspace**

Shared workspace could be a place to store and share files like in Microsoft's Shared Workspace or a system that offers a complete office environment with virtual conference rooms and audio support like Ezenia!'s InfoWorkspace.

- **E-mail**

Electronic mail allows the exchange of text and any electronic files as attachments. A user is connected with his e-mail client to a mail server. The information is passed between different mail servers and can at the end being downloaded from the server. E-mail client can be any computer connected to the network or even mobile devices (e.g. iPhone or BlackBerry). The amount of data that can be transferred in an e-mail is limited by the server. Typical limits are 10 MB per e-mail.

- **File Exchange**

Files can be exchanged as said as attachments to e-mails, but normally the amount of data is pretty small. To exchange files of any size over the Internet ftp (file transfer protocol) is used. The file must be stored on a server, which supports the ftp protocol. The user who wants to download the file from his computer has to know the address (usually as URL) and must have access rights to the server. For the transfer a normal web browser can be used. Some ftp programs are available, which offer a better user interface.

- **Internet Radio**

The Internet offers the possibility to broadcast audio like a radio station. With a special client like iTunes or web browsers the broadcast can be received.

- **Computer Supported Cooperative Work (CSCW)**

CSCW tries to coordinate the work of a team of persons on one document or task by providing version control, a comment process, access rights management, archiving, etc.

- **WWW**

The World Wide Web is a distributed hypertext system. The information is stored on servers and referenced by hyperlinks. Multi-media content such as pictures or videos is embedded in the hyperlink mechanism and can be displayed in web browsers. Programs like Java applets can be embedded in the hyperlink documents and executed on the client system after download.

In the last years the web got very popular and is now widely used in business and social life especially by the younger generation. Web 2.0 is a term describing the trend to more collaboration between the web users. This is made possible by better and more intuitive user interfaces, easier web design and tools to build own web pages by inexperienced users, decreasing cost for internet access and hosting own web sites and community sites like MySpace. Also the application interfaces of web applications can now be seamlessly integrated in other applications (e.g. Google Search).

#### 4.3.2 Person-to-Equipment Communication

Experiments play a major role in research. It can be physical experiments using probes, manipulators and measuring devices or simulators and simulations run on a computer system. Very often the need for remote control exists. This could be done online (teleoperation) or by executing a prepared script (teleprogramming). Sometimes a mix of both methods is applied.

Besides application sharing (see above) in most cases special tools are used.

#### 4.3.3 Person-to-Metamachine Communication

The concept of person-to-metamachine communication deals with the analysis of huge amounts of distributed data in a computer network with intelligent human computer interfaces. Prof. John Markoff

coined the term “Web 3.0” in the New York Times 2006 to describe the next step in the development of the www. Technologies engaged are:

- Intelligent applications (natural language processing, machine learning, machine reasoning, autonomous agents);
- Distributed databases and database integration (semantic web); and
- Network or distributed computing.

The first steps in this develop have been done with client-server computing, remote database clients and agent technology, but it is still a long way to come.

The Wiki as software that allows a user community to edit web pages interactively is one of the first applications, which could be seen as Web 3.0.

#### **4.4 ORGANIZATION AND BUILD UP OF A VIRTUAL INSTITUTE**

Wikipedia defines institute as: “An institute is a permanent organizational body created for a certain purpose. Often it is a research organization (research institution) created to do research on specific topics.” A Virtual Institute in the RTO should be a permanent institution under which specific research projects with a fixed time scale are executed.

The VI needs to have an in-depth knowledge of its subject and is likely to involve some of the leading experts in its research area. It must also have a finely tuned internal and external communication system based on a genuine thrust and a spirit of co-operation between its members and indeed with its customers. A permanent VI staff could provide the corporate knowledge regarding the specific research area which the Virtual Institute represents (e.g. on Human Behaviour representation), Virtual Research issues, maintain critical services, work on standards and their application to be used in this context and give support to questions regarding security and intellectual property issues. This way an in NATO R&D needed capability could be established that supports the rapid formation of ad hoc, multi-disciplinary research teams, accelerates their work by making prior work and related expertise readily available, fosters rapid dissemination of research results, and otherwise aids in the execution and exploitation of relevant research.

Figure 4-1 shows a recommended Virtual Institute Organization with permanent staff elements and temporary projects, which will be executed under the virtual institute. The main structure of the virtual institute, such as operational executive, administration, IT support and VI support would be relatively fixed whereas specific projects and experiments with their national participation could vary.

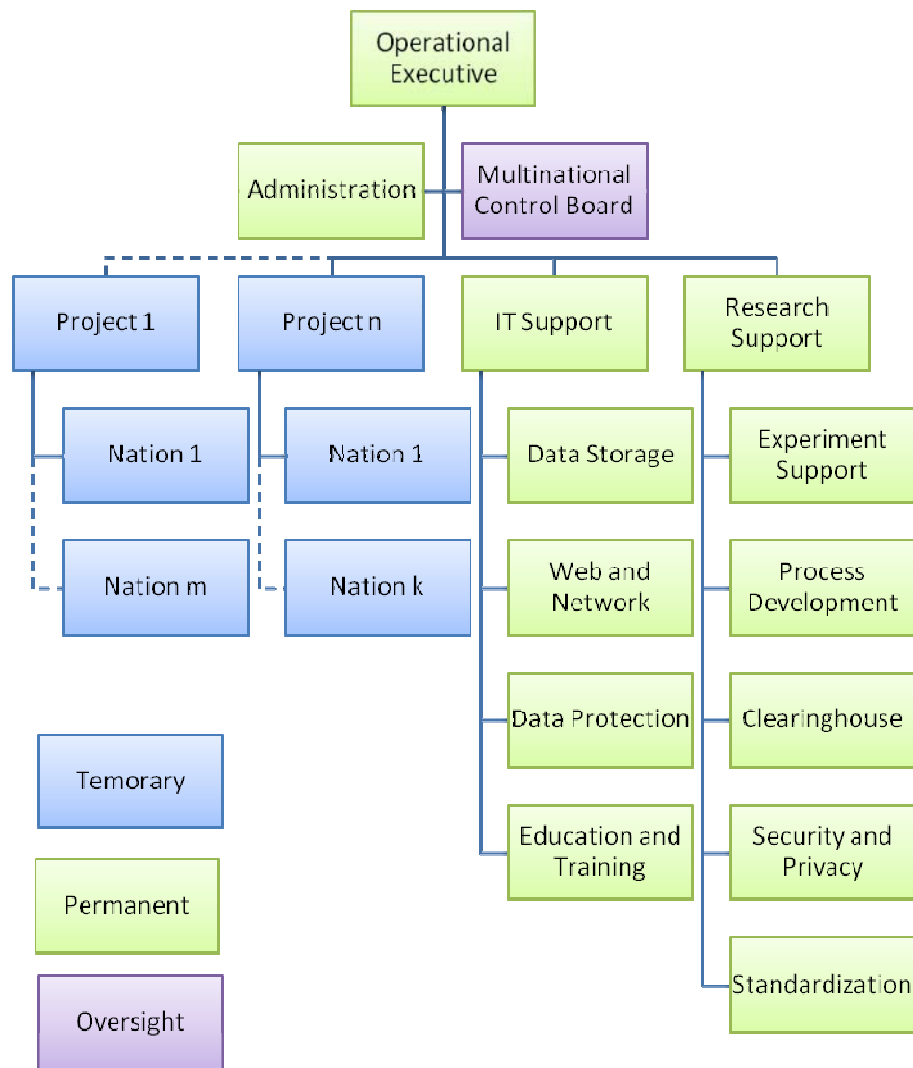


**Figure 4-1: Virtual Institute Organization.**

The operational executive, the administration and the multi-national control board provide guidance and oversight to project teams, aid in the formation of virtual teams and in the coordination between them and the VI permanent staff. They are also responsible for the operation and further development of the virtual institute. The virtual institute should continually evaluate its work, improve organization and procedures and publish guidance for other virtual institutes.

The other permanent staff elements are the IT support and the research support staff.

The IT support is responsible for ongoing technical services for all staff members and the project teams. It aids in making the technical connectivity needed by the virtual teams in order for them to exist and also provide data storage, access, protection, data mining capabilities and security and privacy services for the institute's data. The IT support will assist the virtual teams in placing their raw and analyzed data from experiments and research into permanent storage. IT support will also assist all users with education and training on the IT facilities and how to use them.

The research support staff has two functional areas: the direct support of the project teams in their area of expertise and the further development of the virtual institute regarding the research issue at hand and

## VI CONCEPT

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procedures and management. Direct support based on experience can be given to the project teams in helping with setting up experiments, helping with the evaluation of experiments, guiding project teams through the process of working under a virtual institute, and helping with data exchange issues regarding intellectual property rights and security. Each project team should have one permanent point of contact in the research staff who might be a full member of the project team. The research support staff will be responsible for the function of the virtual institute to serve as a clearinghouse by organizing the peer review of research results from the project teams and for the proper storage with references (for future use on the semantic web). Ideally the research staff would organize the digital library of the institute in a way that all relevant information on the institute's subject can be found on their server or by crosslink to other relevant organizations. The research support could also identify research and development needs and gaps in the particular field of expertise and document the state of the art in the research area of the virtual institute and participate in the discussion of a future roadmap of this research area. Research support should have also a part attached which is responsible for the future development of the virtual institute concept by evaluation of ongoing work and work on process development and standards.

The project teams would be built for specific research project with a limited lifetime. Each project would have a well-defined research objective and when that objective is achieved the team can disband. They would consist of members from different participating nations and NATO HQs and agencies.

The build up of a Virtual Institute includes three work packages (see [9]):

- Establishment and Management with the main objective to define and establish the VI organization and management routines, consisting of:
  - Legal establishment; and
  - Management and administration.

This includes the setup and definition of the virtual institute's research issue and has therefore been done on RTO level.

- Infrastructure with the main objective to establish an effective infrastructure supporting both internal and external cooperation, consisting of:
  - Concept and specifications of the infrastructure;
  - Technical solutions and associated costs;
  - Development of the infrastructure;
  - Deployment and validation;
  - Training and operation; and
  - External users' portal.

A major point of this step is the decision on the infrastructure for the virtual institute. This includes not only IT systems but also facilities to host the stuff and all technical infrastructure. Another important point is the question regarding the financing of the institute. As explained above the virtual institute needs permanent stuff elements to function properly.

- Management and sharing of knowledge with the main objective to secure corporate knowledge – and especially ensure corporate memory, consisting of:
  - Web-based research result and project database;
  - Identification of profiles and experts;
  - Design of knowledge centre; and
  - Development of methods and routines.

This package is an ongoing process, which will be the responsibility of the research staff.

Additionally to the build-up of the institute each of the projects to be performed under the virtual institute has to be planned and set up appropriately. Social and psychological factors have to be considered. So should the project especially when set up with experts from different regions and cultural backgrounds start with face-to-face meetings to know each other better before working in a virtual environment. The set up of the virtual environment must also reflect different personalities in the project and requirements coming from the research topic.

## 4.5 USAGE

This section will discuss the use of virtual institute technology in the RTO with reference to already existing capabilities like the RTO forum with the WISE information panel, the NATO Combined Federated Battle Lab Network and NATO Science, Technology and Research Network (STARNET).

Overall objective of the virtual institute is to provide services to the research community in the RTO as a whole and to special project teams in particular with direct support of them providing a virtual environment. The virtual institute could deliver following products to support study teams in working together (discussion forum, message board, etc.), to publish research results (digital library), to give advice to study teams (SME contact data, legal guidance, checklists) and to conduct experiments (model library, data and scenarios, raw data for analysis):

- **Digital Library or Information Resource Centre**  
The digital library could consist of research documents, project documentation, simulation models including their documentation and scenarios, links to external relevant sources. The RTO web site offers already some of this functionality with access to RTO documents and workspaces for specific projects. No model library for any research area is available. Also no data on scenarios used for research or other purposes (e.g. training and exercises) is available on RTO web.
- **Taxonomy**  
An overall research area or comprehensive taxonomy could be provided. RTO developed together with ACT a cross referencing mechanism based upon a common technology taxonomy (UK MOD), which is provided to each workspace on the RTO web.
- **Discussion Forum**  
A discussion forum can be used project internal or with a wider community of users to discuss current issues. It needs always moderation. In the RTO collaborative environment a forum for each workspace is established.
- **Message Board or News**  
A message board or news allows to post messages for a specified user community. This functionality is on the RTO web available.
- **Shared Calendars**  
Shared calendars allow to place events and to coordinate scheduling in a team. The functionality of shared calendars can be extended to a management of common resources like conference rooms or VTC. On the RTO web are the dates of RTO events placed but on the project level no shared calendars for the teams exist.
- **Virtual Conferences**  
The virtual institute can organize real or virtual conferences to specific topics of its research area or support the set up of virtual conferences for project teams. Live conferences could be broadcasted via TCP/IP or recorded and then podcasted. This is not available at the moment.
- **Lecture Series**  
Lecture series could be supported by a virtual institute the same as conferences. This is not available at the moment.

- **Subject Matter Expert (SME) Contact Data**

A list of SME contact data with areas of responsibility, biographies and references could be provided by the virtual institute for specific research areas. This is not available on the RTO web yet. Each project is responsible for its own contact data but there is no possibility to publish this data or to link it to specific issues.

- **Checklists or ‘How To’ Guides**

Checklists or how to guides for the conduct of projects or part of it (e.g. experiment set up or data sharing agreements) could be made available by the virtual institute. This is only partly available from RTO at the moment.

- **Legal Guidance**

Information regarding legal issues like intellectual property rights or security should be published by the virtual institute for different countries and alliances. A reference to data exchange agreements and procedures should be established. This is not available at the moment.

- **Experiment Data Sharing**

The raw data of experiments could be made available to the community for specific analysis or hypotheses checking. Such functionality is momentary not available and has to be established by each project by itself.

- **Support of (Distributed) Experiments**

The virtual institute can support (distributed) experiments in many different ways. It starts with giving advice to the experiment set up based on experience. It can also provide tools for the execution of the experiment. This can be a virtual environment provided by the virtual institute or simulations, data, scenarios, etc. The virtual institute could also support the evaluation and analysis of the experiment.

## 4.6 DATA EXCHANGE

Security issues and intellectual property rights have an impact on the storage and exchange of data in a virtual institute. Participating nations and organizations have to agree on Memoranda of Understanding (MOU), which constitute the rules for the operation of the virtual institute (umbrella MOU). For each specific experiment or other project an own MOU between the participating parties have to be agreed on. Here it would be helpful if the virtual institute could provide an overview on already existing data exchange agreements, which could be used.

The virtual institute must protect intellectual property rights (e.g. commercial simulation systems used in experiments).

Besides the legal side of security and intellectual property rights the virtual institute must provide technical means to assure that data is stored and exchanged in the right way (e.g. encrypted network). This could make it necessary to install separate infrastructure for different projects. Even if existing networks like the Combined Federated Battle Lab (CFBL) network are used, additional costs might apply. Another issue with secured networks is that they can only be operated in a secure environment, which makes the information exchange with and participation of independent research institutes and universities difficult.

## 4.7 CURRENT RTO WEBSITE

The current RTO website serves two purposes: it represents RTO with its work to the public on the Internet and it provides some of the virtual institute functionality to the RTO with its Panels and technical teams. Therefore the RTO Website is structured to provide access to information and services for the general public and for registered users after login (protected information up to NATO Unclassified and private collaborative workspaces).

The home page provides the latest RTO news and navigation to the various other parts of the site. The information on the home page is publicly available and hence no logon is required. The General Documentation page provides access to RTO documentation and is divided into Public and Protected areas. For example, under the public area there are documents like the RTO Strategy, RTO Charter and some general briefings on the RTO. Examples of protected information are the RTO Operating Procedures, RTO Programme of Work, the RTO Rolling Plan and the RTA internal telephone directory.

Full details of all past, current and some planned RTO activities are available from a single searchable activities page. By selecting a particular activity, it is possible to see also other related areas of RTO research through a taxonomy based linked database along with links to associated publications or future meetings, depending upon the status of the activity. The majority of information on RTO Activities is publicly available, although upon logon users will have access to more information about each activity, including access to a printable version of the Technical Activity Proposal (TAP).

A full calendar of forthcoming symposia, workshops and lecture series is available from the website, where the full theme in both English and French is available along with the ability to enrol through the RTO on-line enrolment process. In addition, prospective Authors can submit their abstracts via the RTO Website for review by the respective Programme Committee.

The RTO website provides for full download of all RTO and AGARD reports up to NATO Unclassified plus an unclassified abstract of reports of a higher classification (up to NATO Secret). The website also has the usual full search and retrieval capability. Access to the full text of publications is dependent upon the classification of each report.

There is a page dedicated to the RTB where users can view decision sheets, presentations and other related information for both past and future Board meetings. This information is protected and as such requires user authentication.

A page has been dedicated to information about the RTO National Coordinators. This page contains a list of the National Coordinator for each nation; part of this information is protected.

Under each Panel/NMSG, there are several sub areas containing information as follows:

- An explanation about the mission and scope of each Panel plus latest news.
- A full list of activities for each Panel is listed, along with details concerning the activity.
- A full list of forthcoming events for each Panel is listed, along with the ability to enrol on-line.
- A full list of the published Scientific Publications from each Panel is listed, and provides for full download of all reports up to NATO Unclassified plus an unclassified abstract of reports of a higher classification (up to NATO Secret). These pages are essentially the same as the main RTO Publications page but filtered to include only those publications for the associated Panel.
- The structure of each Panel is explained along with a list of the national Panel members. This information is protected and hence requires user authentication.
- Pages for the download of relevant Panel documents, for example the Decision Sheets of Panel Business Meetings. This information is protected and as such requires user authentication.

The NATO Science, Technology and Research Network (STARNET) is build to facilitate access to information elements existing worldwide, in terms of science, technology and overall research; it is a database of Web-based data sources, which will allow comprehensive and sophisticated searches. STARNET is designed as a virtual library to provide a “one stop” information resource for policy makers, program managers, scientists, engineers and researchers. It has been designed, as a system that can be adapted to address specific information needs as they arise within the NATO community.

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STARNET is composed of seven scientific areas or nodes as listed on the left of the page. Each node has specific topics assigned, with its own inventory of web-available information resources.

These resources are chosen based on their relevancy to the specific topics assigned to each of the nodes.

In addition to the open and protected information, the Website provides a series of closed private collaborative workspaces for specific members of the RTO Community. The secure closed workspaces correspond largely to the structure of the RTO, being mainly for Level 3 Task Group activities.

Each workspace has the following functionality:

- Workspace News – general news area for each workspace;
- File Explorer – Shared Files and Folders;
- Threaded Discussion – Threaded Message Discussion Board;
- List of Contacts – Specific to each Workspace;
- Useful Web Resources – Area for building a library of links to useful web based resources specific to each workspace; and
- Related Research by Taxonomy – Link to the Taxonomy based research matching algorithm to view possible areas of related research within the NATO R&T Community (currently limited to RTO and ACT LTCRs).

The workspace environment uses the Secure Socket Layer (SSL) version 3.0 protocol and is firewall protected using architecture accredited by the NATO Office of Security and as such can be accessed from computer connected to the Internet with access to HTTP, and SSL (v3) protocol.

## 4.8 VI APPLICATIONS

The need for a multi-national human behavior research virtual institute is apparent in many areas, most distinctly in the area of multi-national command and control (C2). Within this environment, military individuals from various nations must work in a complicated coalition to assemble effective teams. Within these teams, there are several aspects that play significant importance in the formation of effective teams. In addition, the stress of the complex C2 environment in which the multi-national team is employed puts a greater demand on the team to work as efficiently and effectively as possible. To enable multiple nations to form the most effective teams as quickly as possible in a joint command team C2 environment, testing is required to show the strengths and weaknesses of joint team ability. Using these strengths and weaknesses, team members can collaborate and communicate in a more effective manner and the joint command team will perform more efficiently.

### 4.8.1 Exemplar Uses of the Virtual Institute

A wide variety of experiments can be conducted at modest cost and with scientific worth, which in turn can result in better operational performance. In this section we will discuss a few of the types of experiments that can be executed within the VI. One type of experiment that can be performed is a background experiment to determine the differences between the NATO nations as regards their military and national cultures and encode these differences in a knowledge base. One key aspect of the differences between cultures is the socialization process and the differences between customs and attitudes. To accomplish socialization is important but is also very difficult. While NATO nations all work together to cooperate, true operational effectiveness cannot be achieved until socialization among them is achieved, which means that culture differences must be overcome and also misunderstandings due to word usage and custom that are unfamiliar to other parties must be avoided. Traditionally, socialization occurs as a

result of many conversations and interactions that, in bulk, permit some portion of the information necessary for the development of mutual trust and interoperability to be exchanged but while it is not clear how long the normal process takes, the time duration is certainly on the order of days or weeks. Part of the reason for the length of time required for socialization is that it is a hit and miss process and is usually accomplished over lengthy periods of time among people with similar cultures. The challenge, then, is to conduct experiments to determine how to socialize people rapidly across multiple cultures when at this time it is not clear which knowledge about other cultures is most crucial to an operation or to an effective coalition action. The VI can be used to conduct binary and n-ary experiments to determine effective means for accelerating the socialization process and making socialization actions effective. The VI can be used to design and execute experiments that measure development of shared comprehension of situation across coalition and cultures and determine what portions of network-centric benefits only accrue when culture and national differences are considered. For example, in support of the twin issues of trust establishment and coalition member socialization, the virtual institute can be used to help coalition members to rapidly arrive at a common understanding of the coalition members' and coalition's information security capabilities, information security operations capabilities, and NCW capabilities. As the coalition partners increase their degree of operational effectiveness, their reliance upon network resources to retain this high degree of operational effectiveness increases. However, this degree of coalition operational effectiveness can be degraded if the network is attacked and, subsequently, confidence in NCW resources and capabilities starts to decrease. The degradation can pose a problem for coalition NCW operations. We can use the virtual institute to determine how different cultures respond to this circumstance and, thereby, prepare procedures for it and develop doctrine to allow coalition partners to deal with this eventuality.

Even if traditional socialization cannot be replaced, the VI can provide a continuously at-hand capability for interactions among the nations, which can form the basis for understanding and accelerate socialization. Wide area simulation among coalition partners on a regular basis, for example monthly, would speed up the socialization process but is only one step. The VI can also be used to determine the cultural impact on decision making by answering questions like the following:

- 1) Do different cultures/militaries use different information to make decisions when faced with same situation and/or do they use the same information differently?
- 2) How should information be shared in light of the differences in culture and custom so that all partners perceive the situation the same way and reach same conclusion.

The VI can be used to investigate and research key technical and cultural issues that must be addressed if NCW is to be successful for the US and coalition members in a coalition environment. Specifically, issues related to the type of communication that is needed, bandwidth, data security, redundancy, and communication flexibility can be determined using the VI. Experiments in the VI to determine how to maintain cohesion and the will to fight across cultures in a distributed command can also be conducted as well as experiments to determine the new leadership challenges that emerge in NCW that must be overcome. And, since the coalition will be comprised of many different types of computer and communication security mechanisms, the VI can be used to conduct experiments to determine how to securely exchange all relevant and supportive data across a coalition while still preserving each nation's NCW capabilities and a secure information technology infrastructure. Additionally, the VI can be used to assess and model the performance of individuals and of the team (groups, command post, etc.) when the information flow is under cyberattack and the information elements that are used by individuals and teams cannot be trusted. The VI can also be used to determine and model how to counteract the effects of uncertain information and to assess which information is of the most crucial importance under a variety of situations. These models, and the techniques developed to counteract uncertainties that arise due to cyberattack, can have great utility for coalition operations and for operations that have short execution timelines. To our knowledge, the VI would be the first and only environment in which the required experiments and exercises could be conducted securely using wide varieties of coalition members and individuals that are performing individual and team tasks.

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The security of the information technology infrastructure points to the need to investigate information assurance and software protection as they relate to human behavior, socialization, team building, cohesion, and decision-making. Until recently, the need for information assurance and application software protection and security for its data has been addressed through efforts to provide security for the simulation environment using network level resources or operating system level resources. However, the intended targets of the attacks, the application software and its data, have no inherent protection and rely solely upon network-based and operating system based defences for their protection. Even with the use of strong encryption technology, these two forms of cyber-defence have failed to secure applications from a variety of attacks. The record of successful attacks demonstrates that simply placing security defence technology in the network and the operating system, while necessary, is not sufficient to provide protection and security for the application software and data involved in distributed simulation environments. It is increasingly apparent that software and data must be protected using a variety of technologies that could be embedded in the application software and data.

Application security, which is the security embedded in application software and data, will become a more important part of modeling and simulation environments, and hence the VI, as the environments increase in their fidelity and as more locations participate in simulation exercises and experiments. The increase in fidelity will increase the value of both the simulation software and of the data and will make them increasingly valuable targets for attack. The increase in value will also result in more resources being devoted to obtaining the information contained in the simulation software and data. Encrypting the data while in transit between hosts is not sufficient to address the spectrum of security threats to be countered. Threats to the data exist while it resides on a host in unencrypted form and also to the software that comprises the simulation environment. These threats arise because the network and operating system portions of the simulation environment do not provide security to insure the protection of the data and software. Therefore, defences for applications and their data are needed, and these capabilities should naturally be placed in the application because the application layer provides a logical location for the placement of additional protection capabilities. Note that there are pressing research needs that hinder widespread adoption of application security technologies. Some of these research needs include the development of techniques that allow an application to detect attempted compromise, techniques to allow an application to detect tampering, and metrics that permit the objective measurement and comparison of software and data protection techniques.

In our view, there are two main technical objectives for practical software protection as they relate to the VI:

- 1) To make the task of violating an application so difficult that the effort needed to compromise an application is too high for most attackers; and
- 2) To make the task of breaking into an application so time-consuming that most attackers who could accomplish a penetration give up.

As a complementary requirement, those attacks that do succeed must be quickly detected in order to limit the damage inflicted. To attain these objectives, protected software should exhibit five critical properties:

- 1) It should be difficult to change the overall functionality of the software via small, local changes to the code;
- 2) It should be difficult to analyze the software's control and data flows;
- 3) It should be difficult to determine the software's runtime behaviour;
- 4) It should be difficult to attack/subvert the software via its execution environment/host platform; and
- 5) The protection should employ strong cryptographic technologies.

Furthermore, defending/protecting software against attacks and compromise require that applications be aware of their environment and must cautiously interact with that environment. Inputs from users, whether

those users are human or other software applications must be carefully scrutinized. An important adjunct to these principles is security threat modeling, especially as it relates to human behavior and decision-making. The Unified Modeling Language (UML) can be used to portray and modeling application security threats in a manner that is clear and standard as well as extensible. An accurate model of the threats that an application will face and must defeat is an essential first step in determining the defences needed by an application.

Because of the importance of coalition operations, near-term research must also address the problem of protection of software across the entire spectrum of hardware platforms, software, automated insertion of protection techniques into software middleware, and integration of application security techniques with operating system and network-based defensive capabilities is important. For the modeling and simulation community, the protection of VI software is also important and poses several challenges in terms of performance impact, stealthiness of protection, and the proper mix of protection techniques is important for the VI, especially as they relate to the timeliness of decision-making, human behaviors, cultural differences, team building, and socialization.

One of the clearest and most pressing priorities is the need for a lexicon and ontology of modeling and simulation terms as they relate to the VI. These test suites need to include benchmarks, metrics, an evaluation system (or rating system), and security testing scenarios that would allow the modeling and simulation community to evaluate the efficacy of various software protection techniques in modeling and simulation applications and environments and for the way they affect human behavior. In addition to the standardization needs, there is also the need for information that can guide the modeling and simulation community in combining network, operating system, and application security capabilities in a mutually reinforcing manner so as to address threats in a way that have minimal impact upon performance. This need is especially important given the modeling and simulation communities, and the VIs, reliance upon networks and the sensitive data transmitted across them. As a result, there is a need to protect data assets in a distributed simulation environment. Because a distributed simulation operates within a continuously varying environment, the modeling and simulation community, and the VI, would benefit from software protection techniques that can be composed during execution in concert with network and operating system security techniques to maintain a desired degree of security for a distributed simulation even in the face of attack. To achieve this goal, even in part, standardization work can be performed in the VI that can be used to enable components of a distributed simulation environment to establish trust among themselves, exchange security interface information and security requirements information, and continuously monitor the application security performance of the other components of their application and of the distributed simulation as a whole is necessary.

A challenge related to NCW that can be addressed using the virtual institute are the challenges posed by Effects Based Operations (EBO) and the EBO deployment and implementation considerations and tactics that should be used by a coalition against multi-cultural enemies. Because EBO is directed toward the enemy and their perceptions of the battlespace (and thereby indirectly their will and capability) while not distorting coalition members' perceptions and understanding, it is important to understand how to both affect perceptions of the enemy and avoid affecting perceptions of coalition partners. The virtual institute can be used to address both of these challenges regarding understanding of human perception by determining how to conduct EBO in a manner that reinforces coalition will and capability while also undermining those of the enemy. The VI can be used to understand and build models of the human behavior of the enemy, determine how that culture operates, its values, and how an understanding of the culture can be used in EBO.

All of these information security measures should, of course, be aimed at determining the types of technical solutions that are needed to shorten the decision cycle across and within each component of the coalition. Shortening the decision cycle requires development of a common understanding of plans and procedures, development of a common mental model of the battlespace, as well as means for raising and

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maintaining confidence and morale of coalition partners in commanders and coalition technologies, all of which are experiments that can be conducted at reasonable cost in the VI. The VI can be used to host experiments that assess different means for maintaining confidence in information security measures within the coalition.

Given the disparities in information technologies and standards used for communication by the potential coalition members, achieving information synchronization and interoperability in spite of differences in information velocity and transport between coalition members. The differences arise and are a challenge because each force has its own natural operational tempo and own natural information velocity within its own national information technology infrastructures. Clearly, these characteristics will not match across cultures and so devising means that allow coalition members to adapt to the differences in a manner that does force everyone to operate at the slowest member's pace. Furthermore, at this time, multi-national simulation experience indicates that different cultures/militaries use different information to make decisions when faced with the same situation. However, each nation and culture purports to make use of identical information in its decision making process. Addressing this seeming contradiction will allow us to determine the priority for the information that has to flow into each coalition partner from all other partners. Proper prioritization will insure that each partner has the right information that the partner needs at the right time in order for it to act upon the information at hand in a way that is consistent with their culture and decision-making style. The VI can host the experiments required to determine how to address these problems in a manner that minimizes impact upon the decision-making cycle. The virtual institute provides a capability for assessing the effectiveness of data transport between coalition partners and a testbed for evaluating new solutions as they are developed. The data transport capability can be met using a set of XML-based battle management languages (BML) for data transport because an XML-based approach helps to build a capability for translating between the BMLs. There would be one BML for the US forces, one for each coalition member, and one common form that serves as an intermediate form to handle translation from one BML to another. Using this approach minimizes the amount of work required when a new coalition member is added or when new aspects need to be added to the data transmission capability. An XML-based approach will allow the languages to capture the nuances of the different cultures as well as nuances in tactics and operational concepts. The battle management language would need to have the following capabilities:

- 1) Is secure;
- 2) Supports information sharing;
- 3) Is secure at multi-levels across coalition members;
- 4) Allows culture and nuance to be explicitly captured and refined in the coalition battle management language;
- 5) Can express any directive, operations order, etc., including peacekeeping operations;
- 6) Supports change to the battle management language including the ontology and taxonomy and element tags;
- 7) Allows multiple-way mapping between coalition member concepts; and
- 8) Supports web services but also can function with more traditional approaches.

The need to move data among coalition partners also raises some technical and policy issues that the VI can be used to address. The following issues as being the most crucial at this time and can be investigated using the virtual institute:

- 1) Determining what data needs to move;
- 2) Determining how to accommodate bandwidth mismatches between partners;

- 3) Determining how to accommodate command structure mismatches and how to route information to the desired recipient when this occurs;
- 4) Determining how to automatically establish security boundaries and provide coalition partners with available services and credentials; and
- 5) Determining how to show a need to know and need to share data and services with coalition partners.

The virtual institute can provide an environment for testing the technologies and policies required to address these challenges and can provide an environment where solutions can be demonstrated under realistic conditions.

The virtual institute can also be used to develop human behavioral models of coalition cohesion and models of enemy effects based operations. Given the rate of change in technologies and the acceleration in the rate at which coalition cultures must socialize and interact, the virtual institute provides a unique venue for conducting experiments to identify future and emerging technologies that could be exploited to rapidly identify salient background information about individual coalition members as well as other units in the coalition during the run-up to joint operations. The experiments should concentrate on addressing how the new and novel aspects of network-centric warfare that cause interaction challenges and command and control challenges (such as different technologies, cultures, notions concerning the relative importance information, reaction to decrease in NCW capabilities, reaction to reduction in network access, and means used to deal with high taskload) can be remediated using new technologies or new approaches to interaction and command and control. The experiments can be used to determine the salient things at each level of command and across a coalition and determine how technologies can be used to the greatest advantage and which technologies and techniques provide the least benefit or are counterproductive. The experiments can be used to determine how the technologies and techniques need to be changed to accommodate different types of operations and coalitions. Example experiments include, but are not limited to the following. Do personal information sharing/exchange technologies like Facebook and MySpace help or hinder the development of cultural understanding and mutual trust. Do video-teleconferences actually supplant face-to-face meetings, reinforce them, or are personal encounters more important than ever in order to conduct fast-paced actions? What value, if any, do text-messaging and video-messaging have in building a sense of trust, community, and jointness? Which technologies and techniques best counter the expected enemy's operations, especially effects-based operations (EBO), against coalition forces? Which EBO techniques would be of the most advantage to the enemy in developing discord among the coalition? What techniques should be best employed to maintain coalition cohesion and unity of effort? Conversely, the techniques that are counterproductive must be identified.

#### **4.8.2 Assessing Decision Support**

The virtual institute provides an experimental environment for measuring the effectiveness of data transport and the needs outlined in the preceding paragraphs. The experiments will be able to be used to determine the technologies and policies that provide the greatest benefit to users, at least in terms of timeliness of arrival of data, which is especially important within the context of network centric warfare. Clearly, the ability of a network-centric force to operate effectively depends upon its ability to move data through the force effectively and efficiently. However, the obvious accuracy of this statement does not provide sufficient guidance to effectively assess the quality of the data flow, to develop and assess doctrine and policy, and to identify areas within the organization where changes in policy and data flow processes can be changed to the greatest positive effect. To help provide the necessary guidance, we developed a foundation for a formal means for assessing data movement within an organization.

Within a network centric organization, there are two sets of entities: sources of data and recipients of data. Within the organization, let  $r$  be the set of data recipient entities and allow them to be arbitrarily and

uniquely labeled from 1 to  $n$ . Within the same organization, let  $s$  be the set of data source entities and allow them to be arbitrarily and uniquely labeled from 1 to  $m$ . Let  $I_r$  be the data required by/destined for a particular recipient of data and  $n$  be the number of data recipients and let  $I_s$  be the data sent from any source of data and  $m$  be the number of data sources. Then,  $I_r \leftarrow I_s$  defines the instantaneous data volume (in bytes) between all sources,  $s$ , and recipients,  $r$ , of data. We can then define  $\mathbf{I}_1$  as:

$$\mathbf{I}_1 = \left( \prod_{i=1}^n I_{r_i} \leftarrow \prod_{j=1}^m I_{s_j} \right) \quad (1)$$

$\mathbf{I}_1$  is the total instantaneous volume of data moving from all sources of data to all recipients of data within an organization at any given time. This definition is source-recipient topology neutral, technology neutral, and bandwidth independent. Based this definition for  $\mathbf{I}_1$ , it is clear that for a network-centric force to be effective, its data capacity must accommodate peak demands for transmission of operational data in conjunction with simultaneous peak demand for transmission of network management data. Using  $\mathbf{I}_1$ , we define the instantaneous data velocity  $\varpi$  within an organization at a given time  $\tau$  in Equation 2:

$$\varpi_\tau = (\mathbf{I}_{1\tau} - \mathbf{I}_{1\tau-1}) / \mathbf{I}_{1\tau-1} \quad (2)$$

The mean data velocity  $\varpi_m$  for an organization over a given time interval  $\gamma$  is defined as shown in Equation 3. A network centric organization should strive to attain a high value for  $\varpi_m$  as well as a high value for  $\varpi$  during important periods of activity. Two other types of important information flows are the ability of the organization's infrastructure to give expedited handling to important (or priority) information and the ability of an organization's infrastructure to provide communication connectivity between high priority communicants. To determine if the organization's infrastructure addresses these two types of information handling appropriately, we first determine how well, on average, the organization's infrastructure supports information flows between all senders and recipients of information. Let the expression  $(r_i \leftarrow s_j \neq 0)$  be used to indicate that there is message traffic between a given recipient and transmitter of information. Let  $\mathbf{I}_{2\tau}$  be the weighted data movement time required for data to move from all sources to all recipients within an organization for a given time period  $\tau$ , then  $\mathbf{I}_{2\tau}$  is defined in Equation 4:

$$\varpi_m = \left( \sum_{\tau=1}^{\gamma} \varpi_\tau \right) / \gamma \quad (3)$$

$$\mathbf{I}_{2\tau} = \left( \left( \prod_{i=1}^n I_{r_i} \leftarrow \prod_{j=1}^m I_{s_j} \right) \right) \div \sum_{i=1, j=1}^{n, m} \left( \Delta t(r_i \leftarrow s_j) \vee ((r_i \leftarrow s_j) \neq 0) \right) \quad (4)$$

Clearly, for a network-centric organization to be effective,  $\mathbf{I}_{2\tau}$  must be as large as possible for all time periods and  $\mathbf{I}_2$  must also be maximized over all time intervals.  $\mathbf{I}_2$  for a given number of time intervals,  $\gamma$ , is calculated as shown in Equation 5:

$$\mathbf{I}_2 = \left( \sum_{\tau=1}^{\gamma} \mathbf{I}_{2\tau} \right) / \gamma \quad (5)$$

To insure that  $I_{2\tau}$  and  $I_2$  are maximized, there must be no contention for bandwidth within the organization and operational and network management data must be transmitted with equal promptness. While efficient transmission of data is crucial to network centric warfare, not all data is of equal importance, as we have indicated. So, even though  $I_2$  may be acceptable, the organization may not be operating effectively from a network-centric warfare perspective because higher priority information is not given corresponding higher precedence for transmission through the organization's infrastructure. Therefore, we require a metric to assess how well the organization manages the transmission of priority data; the overall efficiency of data transmission for priority information is indicated by the value of  $I_3$ . Let  $I_{3p}$  be the average time for priority data to move from all sources to all recipients of data of that given priority within any given time period  $\tau$  within an organization. Assume that data has only one priority or that it is handled in accordance with the highest priority level assigned to it. Assume there are  $x$  sets of priority data within that same time period, and let  $p$  represent a given data priority for data within an organization, clearly  $p$  can assume any value in the range 1 to  $x$ . Then  $I_{3p}$  for a given message priority  $p$  at a time  $\tau$  is defined as shown in Equation 6.  $I_3$  for all message priorities at a given time  $\tau$  is defined in Equation 7.

$$I_{3p} = \left( \left( \prod_{i=1}^n I_{r_i} \leftarrow \prod_{j=1}^m I_{s_j} \right) \right) \div \sum \left( \Delta t(r_i \leftarrow s_j) \left[ \left( (r_i \leftarrow s_j) \neq 0 \wedge (r_i \leftarrow s_j) \subset p \right) \right] \right) \right) \quad (6)$$

$$I_3 = \sum_{p=1}^x I_{3p} \div x \quad (7)$$

Let  $I_{4r}$  be the time differential between the time,  $t_n$ , when data (of all priorities) is needed by a recipient and the time,  $t_a$ , when it is received by the recipient in a given time period. Then  $I_{4r}$  for a given recipient  $r$  during a given time period is defined by Equation 8:

$$I_{4r} = \sum_{j=1}^m (t_{a_r} - t_{n_r}) \vee \left( I_r \leftarrow \prod_{j=1}^m I_{s_j} \ni (r_r \leftarrow s_j) \neq 0 \right) \quad (8)$$

and  $I_4$  for an organization with  $n$  recipients within that same time period is defined as shown in Equation 9:

$$I_4 = \left( \sum_{r=1}^n I_{4r} \right) / n \quad (9)$$

Table 4-2 summarizes the major metrics/variables defined in this section and a short specification for each.

Table 4-2: Major Metrics/Variables and Their Definitions

| Metric/Variable | Definition                                                                                                                                                                 |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $I_1$           | The volume of data moving from all sources of data to all recipients of data within an organization at any given time.                                                     |
| $I_2$           | The average time for data to move from all sources to all recipients within a time period.                                                                                 |
| $I_3$           | The average elapsed time for priority data of a given priority to move from all sources to all recipients of data of that priority at any given time.                      |
| $I_4$           | The time differential between the time when data is needed by a recipient and when it is received.                                                                         |
| $I_5$           | The time differential between the time when data is needed by a recipient and when it received by the data recipient for a given time period for data of a given priority. |
| $I_6$           | The ability of the infrastructure's performance to scale when data volume increases.                                                                                       |
| $I_7$           | The ability of an organization's infrastructure to transport information between important senders and important recipients of information.                                |
| $\omega_\tau$   | Data velocity within an organization at a time $\tau$ .                                                                                                                    |
| $\psi$          | The efficiency of the movement of data.                                                                                                                                    |

A network-centric force has the capability to share and exchange data among the distributed elements of the force and has access to data whenever and wherever it is needed. However, without metrics we are unable to readily determine when or if the organization's infrastructure has the capability to support network-centric operations. The above measures for data movement within a network-centric organization; measures that allow us to assess the efficiency of data flow, its velocity, the total data flow at any time, and measures to assess the ability of a data transport system to respond to the demands placed upon it during the course of an operation when it is under cyber attack and when it is not. One clearly important parameter within a network centric organization is  $I_1$ . The data transportation system must be able to satisfy any demands placed upon it for data and all other things being equal, a system with a larger  $I_1$  is better than one with a smaller  $I_1$ . Additionally, the data transportation system should strive to achieve a small value for  $\omega_\tau$  under all circumstances, because this will insure that the system can handle the data load and that the system can also respond to changes in demand rapidly.

### 4.8.3 Exemplar Multi-Cultural Experimentation Using the VI

The multi-national research experiment that demonstrated the prototype VI/HBR can be used to investigate the impact of culture on teamwork in both national and multi-national venues. The experimentation would involve conceptual model development encompassing the impact of culture on joint military operations, extending experimentation methods to include process and outcome measures, and identifying products for national use to improve leader and team performance in multi-cultural environments. This experimentation can be executed using a research testbed built around a commercial off the shelf (COTS) computer game, such as Neverwinter Nights™. This game-based testbed, funded by the United States Department of Defense Modeling and Simulation Office (DMSO), is designed to satisfy the need for an inexpensive, standardized, research instrument able to explore basic research questions on teamwork skills, situation awareness,

decision making, task effectiveness, adaptability, and the impacts of personality and cultural traits on these issues. A single experimental design can be executed in all the participating nations to build a baseline of responses from homogenous military teams. Then, that design can be executed with heterogeneous teams comprised of military officers from various nations participating in the baseline experimentation.

The HBR Virtual Institute experiment team collaborated with two NATO RTO groups to further its experimental planning in this area: RTG SAS-050 and an HFM Exploratory Team. The VI/HBR experiment team utilized the main research product of SAS-050, which was a conceptual model of Command and Control (C2). The NATO VI/HBR experiment team analyzed and applied this conceptual model and taxonomy of C2 variables as a starting point for the variables within the cultural modeling testbed to measure for their effects on teamwork and cultural influences to teamwork and leadership. In cooperation with an HFM Exploratory Team, SAS-053 collaborated on the experimental approach to test leader and team adaptability in multi-national coalitions for baseline testing, measurement, and analysis. This experimental plan and approach allows the VI/HBR results to be utilized in two important ways:

- 1) The results can be replicated and validated through additional work outside the current multi-national research groups; and
- 2) The experimental process can be used to implement additional national research that will be of comparable use across nations by incorporating the experimental and testing process enabled by the virtual institute prototype.

The experiment demonstrates the utility and efficiency to be gained by using a virtual institute and its infrastructure to conduct experiments.



## **Chapter 5 – RESULTS AND LESSONS IDENTIFIED**

Based upon the meeting results and investigations conducted by the SAS-053 team, the SAS-053 team recommends establishment of a Virtual Institute and that the Virtual Institute should produce and support a Research Plan for Team, Group, Organizational, and Cultural Modeling Research. The need for a permanent VI is clear, at the time of the writing of this report (2007), the state of the art for human behavior, cultural, group, and team modeling is so primitive that simulation environments can only achieve realistic performance for only very small numbers of automated avatars and this representation is relatively primitive and has not appreciably advanced in capabilities in the last seven years. This small number, typically on the order of tens of avatars with accurate behaviors, results in environments that do not accurately portray the real-world. The improvement of human behavior models requires the incorporation of multiple skill levels and representations of doctrine and they must reflect societal, training, and educational differences. Behavior moderators such as morale, fatigue, stress, fear, information operations, and intent must be modeled and included within the model. Furthermore, the knowledge and modeling needed to be able to accurately model large numbers of people from differing cultures is not available and will not become available unless experiments at large-scale can be conducted at reasonable cost. The virtual institute can perform the required experiments and exercises.

### **5.1 VALUE OF THE VIRTUAL INSTITUTE CONCEPT**

Based upon research and analysis performed to date, the following claims concerning the value of the virtual institute concept can be substantiated:

- Cost-effective development of human behavior models for individuals, teams, and groups that include appropriate behavior modifiers;
- Accelerate the development, use, and re-use of human behavior models across the entire spectrum of NATO's need for the models;
- Rapidly address technical, human behavior modeling, and cultural issues of interest to NATO by rapidly assembling experts from across alliance to address the problem;
- Reduce the cost of human behavior model related knowledge acquisition;
- Rapidly address operational issues of interest to NATO by rapidly assembling experts and military members from across alliance to address the problem;
- Enable cost-effective use of multiple experts from many fields to address a problem;
- Enable future work to effectively build upon prior research and experience where leave-behind from every experiment is readily accessible to all;
- Enable re-use and expansion of existing and to be developed human behavior models by developing standard interfaces and middleware to HBR models, human behavior knowledgebases, and models that portray factors that affect human behavior (such as culture, teams, and experience);
- Provides the most cost effective means for rapidly addressing the need for higher fidelity human behavior and cultural models;
- Provide an environment for test and evaluation of multi-cultural and multi-national information assurance and software protection mechanisms as well as their effect upon human behavior, cultural-based reactions, team building, trust establishment, socialization, and other factors that affect multi-national operations;
- Provide an effective foundation for conducting research on human behavior model verification, validation, and accreditation (VV&A);

## RESULTS AND LESSONS IDENTIFIED

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- The Virtual Institute offers a unique combination of low cost, responsiveness, broad expertise, scientific validity, partnership/collaboration, scalability, access to results, support for analysis, and support to the war-fighter in all domains of concern, not just human behavior modelling; and
- Pioneer and enable rapid exploitation of emerging Web 2.0 technologies, such as wikis, podcasts, telecasts and even chatrooms and myspace-like capabilities, tied to the VI and its projects, for HBR research of all types.

In short, the virtual institute concept is able to provide a broad range of capabilities that are required by NATO by exploiting a large set of the powerful Web 2.0 technologies to address the human behavior and cultural modeling research issues at reasonable cost and in a timely manner.

### 5.2 RECOMMENDED ONGOING VIRTUAL INSTITUTE ACTIVITIES

The goals of the ongoing activities of the Virtual Institute are to push current technologies and research breakthroughs to participating NATO nations, to make VI research and exercise results readily obtainable by NATO member nations, and to encourage use of the VI by researchers to conduct multi-national experiments in HBR and other areas of interest to NATO. In addition, there are a number of activities that the VI should conduct as part of its mission in addition to hosting experiments and exercises. These activities include the following:

- Develop a virtual institute technology development strategy;
- Develop virtual institute metrics and success criteria;
- Develop a virtual institute research plan and strategy (recorded in both standards and a VI wiki);
- Determine the key steps for advancing the virtual institute capabilities and the key technologies needed by the virtual institute to conduct experiments;
- Develop a methodology to assess technical benefits of virtual institute-based experiments and tests as compared to conducting equivalent experiments and tests in one location;
- Develop guidelines for technology sharing among virtual institute participants (recorded in both standards and a VI wiki);
- Develop ontologies for human behaviors (recorded in both standards and within a VI wiki);
- Develop and employ a methodology that can be used to organize a human behavior model library for each country and for all countries as well as enable the development of common human behavior models and model components (interfaces can be documented using podcasts and wikis);
- Develop and maintain a sustained presence within an online virtual world, such as Second Life, for collaboration, information exchange, demonstrations, and hosting of virtual conferences. This same presence can also be used for limited experimentation and presentation of results;
- Develop a virtual institute human behavior model experiment plan;
- Conduct an ongoing podcast lecture series on the virtual institute, HBR, and other VI uses and results; and
- Maintain wikis, podcasts, telecasts, chatrooms, and myspace-like capabilities for community use and for use by each experiment/exercise that are also linked to relevant projects in other Panels in the RTO.

### 5.3 RESULTS

- Support HFM-138:
  - Experiment Setup.

- Support SAS-050:
  - Discussion of Follow on Work.
- Input to RTA Setup:
  - Use of WISE Portal; and
  - Input to VI Meeting.
- Input to RTB Strategic Plan.

## **5.4 LESSONS IDENTIFIED**

The LTSS on Human Behaviour Representation recommended a study on Virtual Institute for Human Behaviour Representation in 2000 to the SAS Panel. In 2002 the exploratory team ET.V started to work on a more detailed study proposal, which was finished in 2003. The study on the Virtual Institute for Human Behaviour Representation started with its first meeting in 2004 and had its last meeting in 2007. In this time from 2000 to 2007 the underlying technology for virtual institutes developed very fast. So are now high-speed web access and tools for collaboration widely available and affordable even for private users. Video, groupware and shared workspaces are now quite common in office environments. Web 2.0 developments (like Apple's me.com, MySpace, Yahoo, BlogSpot, Wikipedia) have especially an impact on the younger generation and made the Internet more interactive. What was proposed with the LTSS became at least in technology terms reality just by itself, it didn't need an RTO study. But nevertheless the use of the new technology and its embedding in the right organization still needs concepts from the RTO. But RTO should think of ways how to make this concept development or guidance for use of new technology faster than with the standard procedures, which took in this case between proposal and results 7 years. Regarding the use of IT technology an established virtual institute could help to play this role.

The study SAS-053 on Virtual Institute for Human Behaviour Representation of supported by 5 nations and ACT (NC3A participation). The two Co-Chairs of the study (USA and NC3A) had a very limited budget for the study work. During the study they gave briefings even on high level (Adm. Bartoli) to ask for financial support for a prototype virtual institute to do experiments, but didn't get the support. The experience from that is that commitment of people (and the study team consists of very committed people) is not enough. The nations and NATO have to commit funds for the build up of an infrastructure if needed.

The team members in 4 of the 5 participating nations changed during the study period. These changes cost time in the study work. It would be good if the study team could stay together and doesn't have to spend time in bringing new members up to speed.

## RESULTS AND LESSONS IDENTIFIED

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## Chapter 6 – RECOMMENDATIONS

### 6.1 RESEARCH RECOMMENDATIONS

As the follow-on to the work of SAS-053, we recommend that NATO take the steps necessary required to lay the foundation for making the virtual institute a permanent capability that is available for all NATO research efforts. Based upon work done to date, SAS-053 has additional recommendations for Virtual Institute use and administration. These recommendations follow.

SAS-053 recommends that one of the first tasks that the RTG should undertake is drafting a Memorandum of Understanding (MOU) to address intellectual property rights, government interests, funding, cost sharing, results sharing, handling of security and classification issues, management, commercial support and other issues that are important to the operation of a virtual institute. The MOU is an important first step in the development of the virtual institute concept because it will lay the groundwork for the scope of the virtual institute and insure the protection of the technologies made available to the virtual institute by the participating countries.

The VI should lead in the development of a technology roadmap for the technologies that the institute hosts and for the HBMs that are under development, especially those that address cultural issues. The roadmap should provide a review of where we stand technologically as well as the issues that the NATO nations need to address. As part of the roadmap, the VI should propose an experiment series that can assess the utility and sufficiency of current HBM data and models needed by the member nations and assess where improved data, research, practices, and standards are needed. The VI can and should also act to maintain a historical record of the development and refinement of the HBMs, including at least the data, experiments, and validation procedures that led to the adoption of each model. New reasoning techniques, potentially hybrids of existing techniques or novel techniques, for unmanned avatars (computer generated actors) used in simulation environments are needed; the VI should lead the way with a series of cross-cultural experiments that assess the value of reasoning techniques like fuzzy logic, Bayesian networks, neural networks, intelligent agents, and case-based reasoning for avatars in military simulation environments and determine which circumstances call for the use of each type of reasoning approach. The virtual institute should also take the lead in the development of standards and practices for teleworkshops and teleconferences as a means for accelerating research and technology dissemination. For the institute to maximize its effectiveness, the VI must actively seek out the involvement and cooperation of national modeling and simulation organizations. The national organizations can aid in developing the technology roadmap, support teleworkshops and teleconferences, cooperate in wikis, podcasts, and webcasts aimed at facilitating discussion, experiment and exercise definition, and describing uses and outcomes achieved with the VI. The national organizations can also aid in research project selection and proposal development, but the VI can serve as the hub and coordination point for member nations activities.

Based on our experience and research to date, the SAS-053 proposes the following three additional recommendations that should be undertaken to Assemble, Test, and Validate an operational, long-term Virtual Institute and thereby demonstrate its utility and also test the process flow and organizational structure. The VI would execute multiple parallel projects simultaneously and fully validate the VI concept and determine the utility of the results without making a great funding or manpower investment. As a first step, we recommend the development of a common ontology(s) and common interface between models for a single experiment that can be conducted to demonstrate the value of the virtual institute concept and also show that valid human behavior results can be obtained using a virtual institute. The second step, much as in the proposed process flow, would be the development of use cases in order to demonstrate the utility of the virtual institute concept. These use cases would be derived from operational needs and the operational environment and would be written to address an operational need via experimentation using the virtual institute. The use cases should be tied to the projects proposed by the participating countries. The third step

## RECOMMENDATIONS

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would be to fully develop a series of projects, derived from the use cases, which can be used to demonstrate and evaluate the complete virtual institute process and organizational structure. When these demonstration projects are successful, a decision can be made concerning whether to develop and deploy an ongoing complete virtual institute.

The virtual institute should be used to develop improved human behavior models of all types at all scales. Improvement in human behavior models requires research on the incorporation of multiple skill levels and representations of doctrine and they must reflect societal, training, and educational differences. Behavior moderators such as morale, fatigue, stress, fear, information operations, and intent must be modeled and included within the human behavior model.

Develop and maintain a presence within Second Life for cultural modeling experimentation and training. Its low cost, ubiquity, flexibility, and ease of access make it an ideal component of the virtual institute for executing any unclassified activities.

A further use for the VI is to assess alternative command post infrastructures in order to determine the infrastructure that yields the most effective network centric operational force. Within a VI that models network centric operations, all of the factors that influence joint military operations, such as armed forces structures, cyberwarfare, doctrine and missions, can be accurately portrayed to derive research results that are applicable to real-world network-centric operational conditions. This research can be used to further other command post research, such as to study Network Centric Warfare Command and Control Issues and develop of guidelines for conducting research to address issues of similar scale and importance to coalition network centric operations. Specifically, in order to come to grips with the NCW C2 challenges for coalition operations, we propose conducting foundational work to identify policy and technical issues that must be resolved to address coalition NCW C2 issues and to conduct coalition command NCW C2 experiments and exercises. The research will determine how to use a virtual institute to address the policy and technical issues impeding coalition NCW-based command and control and will also identify experimental structures and releasability policies needed in order to conduct international experiments. Issues that will be addressed include identification of best practices for use of the institute for C2 experiments and exercises, identifying initial measures of effectiveness that indicate the effectiveness of the virtual institute for addressing coalition NCW C2 issues, and initially assessing the ability of a virtual institute to identify issues and evaluate solutions for coalition C2 within a NCW environment. Underlying these issues is the need to learn how to measure the effect of decisions regarding control and management<sup>1</sup> of people and data within and across teams. The VI can be used for the following:

- 1) To assess types of experiments and exercises that can be conducted using a virtual institute to study coalition NCW-based command and control;
- 2) To develop and describe requirements, desired capabilities, and objectives for a virtual institute that can support coalition C2 exercises and experiments in a NCW environment;
- 3) To identify policy issues that affect the ability of a virtual institute to perform the required experiments;
- 4) To develop guidelines and practices for exercises and experiments that can be used to assess and measure coalition command and control performance in a heterogeneous force;
- 5) To identify issues and evaluate solutions for coalition C2 within a NCW environment as they are related to peacekeeping operations, anti-terror activity, coordination with NGOs, and coalition NCW C2 for combat operations;
- 6) For model validation testing conducted via multiple trials of shared international human behavior models; and

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<sup>1</sup> The difficulties encountered in control and management of resources is a topic receiving more attention of late; see, for example, "An AI Planning-based Tool for Scheduling Satellite Nominal Operations", by Moreno, Borrajo, and Meziat, *AI Magazine*, Vol. 25, No. 4, Winter 2004, pp. 9-27.

- 7) For distribution and testing of human performance data necessary for the development and use of human performance models in many areas of military operations, and for large multi-national experiments that address cultural, team, group, and organizational modeling.

The result of this effort would be a code of best practices that codifies the information concerning how to use the virtual institute, how to setup and execute experiments in the VI, how policy issues should be addressed for an experiment, which legal and intellectual property issues must be addressed before and after an experiment, and how to best exploit the facilities of the VI for to achieve an experimental objective. The achievement of these seven objectives, the guides, and the code of best practices should not be committed only to paper or placed on the web but should be augmented by wikis, podcasts, and webcasts so as to more deeply document these products but also facilitate and capture discussion of the products.

An additional recommendation of SAS-053 is that the RTG improve cooperation between the HFM, IST, and SAS Panels, the NMSG, and NC3A to support RTG in its development and demonstration of a broad-scale NATO virtual institute capability. To achieve this goal, SAS-053 suggests the cooperation and coordination with other interested (and necessary) Panels to participate in the RTG for the VI. In our view, HFM is needed for the for the HBR technical aspects, IST is needed for the virtual institute infrastructure aspects, and SAS is needed for the concept definition, integration, and exploration aspects. In addition, work must be performed in conjunction with SAS for operational analyses support, and NMSG is needed for the support for use of many of the HBR developments in the M&S arena.

For the virtual institute to operate effectively, its cybersecurity must be insured. While we have addressed some of these issues, more remains to be done. A major question that must be addressed is the cost of protection as related to its benefits. Cost can be broken down into three parts: efficiency cost (what is the performance penalty of a technique or combination of techniques), implementation cost, and maintenance cost (i.e. what maintenance cost does the technique impose?) Another question that must be addressed is how to assess and evaluate the costs and benefits of different approaches to VI security in a multi-national setting to that the VI can make informed decisions about the degree of protection needed based upon the sensitivity of the experiments, software, and the costs involved in applying the required application techniques. Another major research question is software protection metrics as they relate to the virtual institute. Some metrics that must be refined further are resilience (a measure of how difficult is it to defeat a technique), obscurity (a measure of how difficult it is to determine if a particular protection technique has been employed), and expected longevity (a measure of the length of time that a protection technique will afford a worthwhile degree of protection) of each protection technology, the costs and benefits of different mixtures of protection techniques, and the level of protection required for a given application and simulation environment as a whole.

Other near-term research needs regarding cyber-security for the VI are clear. One need is for the development of standard test suites that can be used for evaluation of software protection methodologies in a scientific manner so that the security of the VI can be verified on a regular basis. Standard testing should be coupled with the development of data protection technology assessment standards, standard data sets, and methodologies for evaluating data protection technologies. A further need is for the development of international standards to promote interoperability and trust and insure that systems operate at equivalent levels of application/software security when international simulations are conducted. There are other important research needs as well. One of these needs is a methodology that can be used to determine, in a standard manner, the degree of protection required for the VI for a given purpose and for its simulation environment as a whole. A further need is for the development of standard attack profiles that are coupled with intelligent agents in order to enable rapid, autonomous evaluation of the effectiveness of a defence within a distributed simulation environment (as suggested by Shrobe). Of course, the multi-cultural and multi-national information assurance and software protection mechanisms as well as their effect upon human behavior, cultural-based reactions, team building, trust establishment, socialization, and other factors that affect multi-national operations must be investigated.

## RECOMMENDATIONS

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We believe that the utility of the virtual institute and human behavior modeling would be highlighted and interest in these technologies would be increased if the next Panel focused on the development of a tool as a result of the Panel's efforts. Our suggestion for the tool is the development of a multi-national, coalition submarine warfare simulation environment. This environment would provide opportunities for cultural and team research, modeling, and simulation within each submarine as well as for cross-cultural and multi-national modeling and simulation in the command and control of submarine operations. Given the increasing importance of submarines to the control of littoral areas and maritime chokepoints as well as for the protection of surface ship battlegroups and supply ships, a successful tool would insure its adoption and use as well as interest in further development of the virtual institute concept and interest in human behavior research.

One area of clear importance to the Virtual Institute that remains to be addressed is increased participation by the member countries in various projects, which can be accomplished by a series of capabilities briefings delivered at key meetings and via the internet. Additional projects from each participating country will be the foundation for the exploration of the complete NATO VI concept, which will lead to a recommended design and development process for a VI for HBR and for virtual institutes for the other six Panels.

The study team discussed recommendations to the RTO for follow on work in the area of human behaviour representation and the use of the virtual institute technology. The following recommendations are given in the priority the team gave to them (highest priority first).

## **6.2 SAS RSG – SETUP AND ADMINISTRATION OF HBR VI BY RTA IS**

### **6.2.1 Description**

A virtual institute for modelling military-related individuals, teams, groups, platforms, and organizations must be established creating a Web-based clearing house of databases, models and model components, standards, and requirements to support multi-national research and development on human behaviour modelling. A Wiki for HBR and a MySpace for the HBR community should be provided. The technical IT support staff of the virtual institute could be RTA IS. The research support staff and the lead of the virtual institute with the scientific oversight should come from the nations.

### **6.2.2 Military Benefits**

The virtual institute will provide an essential mechanism for information exchange across the NATO nations, reducing duplication of effort and maximizing national capabilities in the domain of human behaviour modelling.

### **6.2.3 Justification**

The virtual institute for modelling human behaviours is called for in the NATO M&S Master Plan (3.3.3: exchange of information).

### **6.2.4 Short and Long Term Outcome**

Short term: The short term outcome will be the creation of a Web-based clearing house for information related to human behaviour modelling for military applications.

Long term: The long term outcome will be the multi-national capability for reduced build-time costs in human behaviour modelling.

### **6.2.5 Required Resources**

NATO RTA for virtual institute infrastructure and technical IT support staff and national commitment and resources for virtual institute infrastructure on their side and research support staff.

## **6.3 HFM RSG – HBR TEAM AND ORGANIZATION ONTOLOGY DEVELOPMENT**

## **6.4 HFM RSG – MULTI-NATIONAL EXPERIMENT HFM-138 FOLLOW ON**

## **6.5 HFM RSG – ADOPT EXISTING TECHNOLOGY IN DEVELOPING PODCAST LECTURE SERIES FOR RTA**

### **6.5.1 Description**

Many universities and research institutes use already podcast technology to deliver lectures on the Internet (e.g. on iTunes). NATO should use this technology too to make existing lecture series and new lecture series available for the interested public. Lectures with unlimited distribution could be placed on the RTA web site whereas classified material could be placed on the RTA web side's closed area (NATO Unclassified) or on the NATO Secret network. From the human factors community the layout of such podcasts and the setup of a facility to cover the lectures should be supported.

### **6.5.2 Military Benefits**

The availability of lecture series will foster a better information exchange and help reducing duplication of effort and maximizing national capabilities in the research domain.

### **6.5.3 Justification**

Lecture series are part of the RTO procedures and intended to distribute research results to all participating nations. A better distribution of lecture series to the research community is a goal of the RTO.

### **6.5.4 Short and Long Term Outcome**

Short term: The short term outcome will be a lecture series which can be delivered on the Internet.

Long term: The long term outcome will be the setup of a facility to produce podcasts for lecture series and procedures based on a human factors analysis.

### **6.5.5 Required Resources**

NATO RTA for technical infrastructure and national commitment and resources.

## **6.6 SAS RSG – DATA EXCHANGE PRACTISES IN NATO**

### **6.6.1 Description**

The work on the study showed that no overview on data exchange practices in NATO exists. A study should be started to provide the research community with an overview on the issue and a list of resources where respective information could be found in the nations and in NATO. The study should also investigate into the opportunity in building up an organizational element where this information can be stored and maintained.

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### **6.6.2 Military Benefits**

The availability of an overview on data exchange practices and a reference on agreements will foster a better information exchange and help reducing duplication of effort and maximizing national capabilities in the research domain.

### **6.6.3 Justification**

Data exchange agreements are necessary for multi-national research.

### **6.6.4 Short and Long Term Outcome**

Short term: The short term outcome will be an overview on the issues and the identification of an organizational element to be build up for the future to store and maintain a reference.

Long term: The long term outcome will be an organizational element.

### **6.6.5 Required Resources**

NATO and national commitment and resources.

## **6.7 HFM RSG – THE USE OF VIRTUAL WORLDS FOR NATO R&D IN HBR**

## Chapter 7 – REFERENCES AND BIBLIOGRAPHY

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## **Annex A – ET.V FINAL REPORT**

### **NATO STUDIES, ANALYSIS, AND SIMULATION (SAS) PANEL ADVISORY REPORT**

### **A VIRTUAL INSTITUTE (VI) FOR RESEARCH ON HUMAN BEHAVIOR REPRESENTATION (HBR)**

### **NATO SAS PANEL EXPLORATORY TEAM ET.V – FINAL REPORT**

#### **EXECUTIVE SUMMARY**

The topic and focus of the SAS-ET.V exploratory team was derived from a previous NATO Long Term Scientific Study (LTSS/51) on Human Behavior Representation sponsored by the SAS Panel. The purpose of the LTSS was to provide a report for the use by NATO and national authorities on the implications of technological developments to military operations over the next ten to fifteen years and to provide research planners with recommendations for research that address/investigate the implications of projected technological developments. Of particular interest to this project, under LTSS/51, their recommendation of highest priority was to establish a NATO RTO exploratory team to investigate the feasibility and utility of assembling a virtual institute for research on human behavior modeling (NATO, 2001). Specifically, the virtual institute was to be established for the purpose of modeling military-related individuals, teams, groups, platforms, and organizations in their performance of military operations and tasks. The virtual institute was envisioned as a NATO resource that would accelerate technology dissemination in specific technology areas that would include development of a web-based clearing house of databases, models and model components and developing standards, and requirements to support multi-national research on human behavior modeling. This particular LTSS/51 recommendation was presented to and approved by the SAS Panel, which in turn established SAS-ET.V. The objective of this SAS-ET.V was two-fold. Firstly, SAS-ET.V is to advise the SAS Panel and, through cooperation with other RTO Panels, the RTO on the technical merit and feasibility of establishing a virtual institute within NATO. Secondly, the SAS-ET.V is to advise the SAS Panel and, through cooperation with other RTO Panels, the RTO the feasibility of enabling multi-national research and development in human behavior modeling by using the virtual institute concept.

To address the two objectives for the Panel, several different activities were undertaken during the past year to assess the feasibility and desirability of the two concepts. As a first step, an exploratory team was formed and three meetings were held to discuss technical feasibility of the concepts, to conduct technical interchange and to assess NATO-wide support for the concepts. In addition, team members participated in their individual countries' technical activities related to the two concepts in order to assess their own countries' technical experts' opinions concerning the concepts as well as support for the concepts and commitment to their execution. A final area of endeavor was an ongoing assessment of the technological foundations needed to implement and operate a virtual institute. In brief, there is support for the concepts; the technologies needed to implement the concepts are available and have been, in many cases, demonstrated; and there is widespread belief that the NATO community would benefit from the virtual institute concept and that human behavior representation is an appropriate choice for the demonstration of the virtual institute concept.

In light of the research, recommendations made by colleagues, and other investigations conducted over the past year, the SAS-ET.V team recommends that a RTO Task Group (RTG) be established to develop a demonstration Virtual Institute and that the Virtual Institute should produce a Research Plan for Team, Group, Organizational, and Cultural Modeling Research.

## A.1 INTRODUCTION

The continuing acceleration of the rate of change of technology development and the ever increasing pressure to maximize the benefit of scarce military resources point to a need to change the manner in which NATO conducts research and disseminates research results for exploitation. While in the past activities such as conferences, workshops, and meetings have served the community well in organizing and disseminating information, they no longer are sufficient to allow scientists and decision-makers to remain apprised of relevant scientific developments and so a new approach to managing, conducting, and disseminating research that augments traditional means is indicated. At this time, it is clear that a capability is needed that supports the rapid formation of ad hoc, multi-disciplinary research teams, accelerates their work by making prior work and related expertise readily available, fosters rapid dissemination of research results, and otherwise aids in the execution and exploitation of relevant research. Because of the academic nature of the activities to be conducted and because the organization would only exist within cyberspace, this capability is called a **virtual institute**. The technologies underpinnings needed to implement a virtual institute have only recently become available at a cost and performance that makes their use efficient and effective for all NATO members. In order to make the virtual institute an integral part of the NATO research structure, all that must be done is to bring the foundational technologies together in a manner conducive to matching the information dissemination capability with the research execution capability and to demonstrate the technical feasibility and savings that would accrue due to the proper exploitation of available technologies. After a year of study and effort, the structure and operation of the virtual institute is apparent and the team strongly encourages execution of a proof of concept demonstration in the human behavior representation (HBR) arena within the RTO Task Group framework. The remainder of this report documents how the exploratory team arrived at its conclusions, the basis for its conclusions, and its suggestions for the organization and operation of the virtual institute.

The topic and focus of the current SAS-ET.V exploratory team was derived from a previous NATO Long Term Scientific Study (LTSS/51) on Human Behavior Representation sponsored by the SAS Panel. The purpose of the LTSS was to provide a report for the use by NATO and national authorities on the implications of technological developments to military operations over the next ten to fifteen years and to provide research planners with recommendations for research that address/investigate the implications of projected technological developments. Of particular interest to this project, under LTSS/51, their recommendation of highest priority was to establish a NATO RTO exploratory team to investigate the feasibility and utility of assembling a virtual institute for research on human behavior modeling (NATO, 2001). Specifically, if implemented the virtual institute was to be established for the purpose of modeling military-related individuals, teams, groups, platforms, and organizations in their performance of military operations and tasks. The virtual institute project's work included creating a web-based clearing house of databases, models and model components and developing standards, and requirements to support multi-national research on human behavior modeling. This particular LTSS/51 recommendation was presented to and approved by the SAS Panel, which in turn established SAS-ET.V. The objective of the SAS-ET.V is two-fold. Firstly, SAS-ET.V is to advise the SAS Panel and, through cooperation with other RTO Panels, the RTO on the technical merit and feasibility of establishing a virtual institute within NATO. Secondly, the SAS-ET.V is to advise the SAS Panel and, through cooperation with other RTO Panels, the RTO the feasibility of enabling multi-national research and development in human behavior modeling by using the virtual institute concept.

### A.1.1 Definition of a Virtual Institute

After starting the process of defining the capabilities required to execute distant research programs and to serve as a repository of research results and knowledge, the team determined that a formal name for the type of proposed virtual organization was needed. After some discussion, the term **institute** was selected because of its positive connotations and its research orientation. Additionally, the term institute is a richer descriptive term than alternative terms, such as laboratory, testbed, or workshop and also has more of a

connotation of being distributed. The term institute also has more of connotation of support for broadly scoped research investigations than the term laboratory, which generally has a connotation of a narrower research focus. The term testbed lacks the connotation of scope and permanence of organization than institute, an institute generally has a long lifetime and connotes some sort of permanence, whereas a testbed exists until the end of its test function and then is dismantled. In the team's view, a testbed would be a natural component of an institute. By using the term institute a number of other components of the organization could be inferred that would not even be implied by the use of the words testbed or laboratory; some of these additional components of the organization would be a library and clearing house. Calling the product an institute is the consensus of ET.V and also seems to be the dominant choice of the colleagues with whom we have discussed the project.

### **A.1.2 Capabilities/Functionality Requirements for a Virtual Institute**

To provide the breadth of services needed by institute users, the institute would require a number of capabilities. The institute should be able to provide training, electronic library, news center, and host for exercises/demonstrations. The institute would focus on addressing new areas of need for NATO, such as crowd modeling, cultural modeling, and joint training (standard military applications). Some example capabilities that should be provided by the virtual institute and must be developed within an international venue would be to serve as a clearing-house for research results, library, study coordination, testbed hosting, and library. A prime function would be distribution of validated and nation-specific human performance models to NATO members and organizations that need them. An associated required capability is the ability for promulgating information concerning the availability of models and their characteristics to member nations and national organizations. In addition, the institute must be able to provide an overview and insight into ongoing academic research, the theoretical and experimental underpinnings for the different models that it provides, and advice and theoretical, as well as practical, justification for using certain models within a given simulation or real world environments.

The virtual institute could also vitalize the development of cross-national academic research support for model development and support for model validation. More importantly, because it is virtual, the institute would be able to support multiple parallel research efforts and assist the efforts and model development in general by providing facilities and access to researchers to support and energize high-bandwidth exchange and comment about data and experimental programs between researchers and the military community during experimentation. The institute would help researchers to maximize the results of their efforts and the utility and relevance of their research results by giving them ready access to the research results of parallel, ongoing efforts and supporting commentary and collegial interchange about the research in real-time. The virtual institute would thereby maximize the return on research investment by allowing researchers to incorporate and exploit for their own research other relevant results from any member nation as it is produced. This exploitation could occur while the work is ongoing and thereby allow researchers to test and validate parallel research results during the course of their own experimentation. The institute would also allow developers to readily access researchers whose work is relevant to their development and obtain their assistance and guidance in using the results of their research in the development project. The virtual institute would allow the researchers to accomplish research related activities, such as validation and peer review, in a few days or hours instead of months; thereby accelerating the rate of progress on research, development based on research results, and the transition of research results into the operational community. In short, a virtual institute could dramatically shorten research and development time and shorten the length of time that lapses between discovery and operational use.

Another function of the virtual institute would be to provide cross-referencing and linkage services between academic literature and models developed at the institute and in the individual nations. The cross-referencing would take the form of a semantic web to support research and development by forming links between models stored and indexed at the institute and the supporting research/literature for the models. Another function that the institute can fulfill is to disseminate the information and data developed via research

projects via the web, institute databases, and virtual conferences. Another way to exploit the institute and its capabilities may be to determine how discrete value systems influence behaviours across ethnicities and other societal groups. This issue is an important research question with practical military implications and applications for the results of the research, but it has not been undertaken to date because of the cause of assembling the requisite international team. The institute can take the lead in addressing this important issue since it need not bring all of the researchers to one location for them to perform their work, rather they will be able to remain in their own labs and develop an international joint experimental plan to address the research issue. The institute can also take the lead in developing standard ways for describing and interfacing to computerized models so that cross-linkages between models and their supporting data and source authorities are established and so that the models and the linkages are expandable.

The institute should also be poised to lead in the development of a technology roadmap for the technologies that the institute hosts. The roadmap can provide a review of where we stand technologically as well as where we need to go. As part of the roadmap, the institute can assess where we have data and models needed by the member nations and where we need data as well as where we need standards. The institute can and should also form some sort of historical record so that there is a record of how the models were developed and the data were acquired as well as how the models were validated. The Virtual Institute should also support collaboration and virtual meeting support and support distance learning with the goal of providing standard meetings/open forums at traditional workshops and conferences such as BRIMS, ICCM, and other conferences in order to engage the research and military application communities and make them aware of the institute, its abilities, accomplishments, and community needs. The virtual institute should also take the lead in the development of teleworkshops and teleconferences as a means for accelerating research and technology dissemination and to minimize the infrastructure required to host and operate a workshop or conference. In our view, if the institute is to maximize its effectiveness, the institute must actively seek out the involvement and cooperation of national modeling and simulation organizations. The national organizations can aid in developing the technology roadmap, support teleworkshops and teleconferences, and aid in research project selection and proposal development. A further important function of the participating nations is to provide funding to the institute.

One topic that must be addressed in detail in the operation of the institute given its reliance upon networking capabilities is network and application software security. While improvement of security capabilities in these technological areas is ongoing among many of the member nations, the institute must address data, application, and network security issues within its own context by drawing upon member nations capabilities and research results so that it to operate effectively and securely.

### **A.1.3 Application Focus for a Virtual Institute: HBR**

As an initial research arena to demonstrate the value and viability of the virtual institute concept, SAS-ET.V recommends human behavior representation (HBR). The group's examination of major HBR conferences and workshops showed little evidence of cross-national or multi-national cooperation and research efforts in HBR, as a result most HBR results are nation and culture specific. The proposed virtual institute would foster and broaden multi-national cooperation and foster development of multi-national and cross-cultural human behavior models. As a result of the virtual institute's ability to foster and accelerate international cooperation and research teaming, within HBR the research focus would be on the development of representations for human behaviours that are relevant to military simulations and operations across the nations. The charter for the virtual institute investigations into HBR would encompass the modeling of model team, group, and organizational behaviours in light of different influences that come to bear on their behavior based upon a number of factors. A few of the factors that have been identified and that are in need of research and development are the effect of societal groups: cultural, religious, and ethnicity as part of and modifiers to the HBR. A central research issue that the virtual institute's HBR research must address is whether to consider the group as a set of individuals that come together to form a group or whether to model the group an atomic unit that can possibly decompose

into individuals when necessary. The virtual institute can play a key role here because it can foster international research into these topics as well as help investigators to determine the effect of culture and nationality on these issues. Research also needs to be conducted to identify the different crowd types to be modeled. Another final research arena that has been identified for the virtual institute is the development of quantitative and qualitative methods for the representation of the groups and their responses. A final research arena that should be a key virtual institute research topic is investigation of team situational awareness as a component of HBR.

Within the HBR research focus arena for the virtual institute, we believe that the guiding principle should be the identification of applications that have high relevance to military missions and needs, the applications should have a clearly identified need and would be operationally helpful and relevant across the nations. With this focus, the virtual institute would be able to insure that its research would be directly applicable to military development and operational areas across the nations. For example, one clear arena of relevance is the C4I application area, in this arena the institute could be used to allow the research results to service the operational need. Another important research focus arena with high operational relevance is special operations forces; especially the response of different cultures to information operations. As such, the cultural modeling aspects of the virtual institute's HBR research would be of critical importance in order to develop and maintain a useful model of the response of different cultures to information warfare and other non-traditional types of warfare. The institute would provide a natural setting for cultural modeling experiments since it would provide ready access to a wide variety of cultures at minimal cost. A final research and application area for the virtual institute would be negotiations, both in a formal setting as well as in ad hoc settings in operational, deployed environments, and the effects of various components and influences of HBR on negotiation strategies and tactics. As a result of the multitude of international research efforts that the institute could foster and collate in a manner heretofore unachievable, one other function of the institute that would valuable would be the development of composable HBR data models and means for storing data in a standard manner so that it can be reused across experiments. In addition to having a standard baseline model, the model would also, because of the transnational focus of the institute, require the capability to accept culture and national specific modifiers on behavior as "plug-ins" to the baseline behavior model. In any event, the virtual institute would certainly be in a position to play a key role in the development, evaluation, and validation of an international baseline human behavior model as well as with identifying and developing important culture and nation specific factors that come to bear upon the baseline model.

## **A.2 ET.V OPERATION AND DOCUMENTATION**

### **A.2.1 Participating Nations/Organizations**

The following countries and organizations are participating or have expressed an interest in participating in the SAS-ET.V effort and the possible follow-on work in the development of an HBR Virtual Institute:

- Germany;
- United Kingdom;
- Turkey;
- Belgium;
- United States;
- Netherlands;
- Canada;
- NC3A; and
- ACT.

### **A.2.2 Focus Area of NATO ET.V**

The SAS-ET.V has refined a preliminary multi-national concept for a NATO RTO Virtual Institute for HBR. This concept includes a description of products the institute should provide, a description of resources needed by the virtual institute, the development of an organizational structure and architecture for the virtual institute, and a concept of operation for the virtual institute, including virtual and real meetings. SAS-ET.V is composed of experts in the two central technical issues faced by the exploratory team:

- 1) The creation of a web-based/network-based virtual institute; and
- 2) The institute's initial application on human behavior modeling.

The responsibilities of the current ET.V team are to inventory and characterize the team, group and organizational models currently available (taken directly from the LTSS/51 effort), define requirements for models in this domain considering the range of applications of potential interest across the NATO nations, and to create a research roadmap to address identified shortfalls and opportunities. These tasks will be accomplished using the demonstrator Virtual Institute. It is clear at this point in the team's progress that to support the research, development, and validation of models needed to make current NATO military needs a reality, a multi-national effort in the understanding and modeling of human behavior and the sharing of the modeling results across nations is needed. It is also apparent from the team's efforts to date that the development of a virtual institute for research in human behavior representation (HBR) will enable the multi-nation cooperation necessary for modeling human behavior to address future modeling and simulation requirements and may be able to minimize costs.

Since the field of human behavior representation is so broad, the SAS-ET.V was chartered by the SAS Panel to investigate a few specific areas of HBR using the virtual institute concept and to evaluate the virtual institute concept within these specific areas of HBR. A main focus is on the development of representations for human behaviors that are relevant to military simulations and operations, including team, group, and organizational behaviors. Within this focus there is also the need to address the effect of societal groups: cultural factors, religious background, and individual ethnicity as well as to develop quantitative and qualitative methods for the representations of the groups and their responses to a variety of situations. Another major focus for the ET.V is to determine whether the group is a set of individuals that come together or is it a group that is a unit that can possibly decompose. A third focus is the identification of experiments based upon identified broad areas of need, which include the need to identify target crowds types for modeling; the response of different cultures to information warfare activities; and the need to identify team situational awareness. Another crucial goal for IT.V is to identify applications that have high relevance to military missions and need, such as a C4I application area, negotiations, or an application area that supports special operations forces needs.

### **A.2.3 Schedule and Meetings Focus**

To accomplish the taskings and produce its required report as set forth by the SAS Panel within the time allotted, the ET.V pursued an aggressive schedule that allocated a total of one year for the complete effort. To achieve the schedule and organize the work, the SAS-ET.V program of work and work schedule was broken into three main meetings over the course of the year. The first meeting was held in October 2002 at the Air Force Agency for Modeling and Simulation in Orlando, FL. The focus of the first meeting was to determine the interest of the country participants in the concept of a virtual institute for HBR and their ability to participate. Each country representative presented a statement of their relevant research efforts and their particular interest in the SAS-ET.V effort. These country statements included discussions of the representative's background, organization, and potential contribution to the SAS-ET.V work and a future HBR Virtual Institute Technical Team. During the working session, SAS-ET.V discussed a draft HBR virtual institute Terms of Reference and then went directly to work defining the Technical Area Plan (TAP) required to define and complete this NATO SAS-ET.V effort. The final discussions during the

first SAS-ET.V meeting concentrated on the focus and content of the final work product for the team, an advisory report to the NATO SAS Panel and RTO. The Technology Area Plan (TAP) for the SAS-ET.V was adopted by the team during its first meeting.

The mid-term meeting for SAS-ET.V was held in May 2003 in conjunction with the 12<sup>th</sup> Behavior Representation for Modeling and Simulation (BRIMS, formerly the Computer Generated Forces and Behavioral Representation Conference). This meeting focused on defining the structure and organization of the HBR Virtual Institute and the VI's interactions and operational requirements. The team also discussed the necessary cooperation and coordination necessary with other RTO Panels, namely the HFM Panel, the IST Panel, and the NMSG. Each team member was tasked with identifying and gaining support of at least one, preferably two, program(s) within their representative countries that would be candidate programs for inclusion in the prototype HBR VI.

The final meeting of SAS-ET.V was held in September 2003 at NC3A in The Hague, Netherlands. The final meeting allowed the team to finalize its efforts in documenting the requirements, operation, and future of an HBR VI. The final team meeting also discussed the recommendations to the SAS Panel and RTO on the establishment of a RTO Task Group (RTG) to begin the implementation of the HBR VI development plan defined in the SAS-ET.V advisory report and reported on the individual country project interested in participating in the HBR VI prototype.

## **A.3 APPROACH FOR A PROTOTYPE VIRTUAL INSTITUTE**

### **A.3.1 Requirements Overview**

The work group identified a number of requirements for the HBR virtual institute. The number of requirements identified to date greatly exceeds the space available for the paper, some of the more important requirements identified to date are the following:

- 1) Develop a virtual institute technology development strategy;
- 2) Develop virtual institute metrics and success criteria;
- 3) Develop a virtual institute research plan and strategy;
- 4) Determine the key steps for developing the virtual institute and the key technologies needed by the virtual institute to conduct initial experiments;
- 5) Develop a methodology to assess technical benefits of virtual institute-based experiments and tests as compared to conducting equivalent experiments and tests in one location;
- 6) Develop descriptions of partitions of work between national participants based on capabilities and national interests;
- 7) Develop guidelines for technology sharing among virtual institute participants;
- 8) Identify and prioritize experiments and tests that are of common interest to the participating countries;
- 9) Develop ontologies for human behaviors;
- 10) Develop and employ a methodology that can be used to organize a human behavior model library for each country and for all countries as well as enable the development of common human behavior models and model components;
- 11) Develop a virtual institute human behavior model experiment plan;
- 12) Determine common behaviors and country specific behaviors via experiments;

- 13) Determine commander behavior modeling techniques; and
- 14) Develop a sequence of experiments and tests that will demonstrate benefits and desired level of international cooperation for virtual institute human behavior model development.

In addition to the above requirements, the HBR virtual institute should provide other capabilities such as serving as a clearing house for research results, providing a library of research results, ongoing academic research, and experiments, insuring that HBR studies are coordinated between nations, and serving as a testbed host for distributed experiments. In our view, a prime function of the virtual institute would be the distribution of human performance models to organizations that need them. The institute should also serve to foster cross-national academic research support for HBR model development and support validation of models. Another important contribution that the institute can make is the development/promulgation of standards or measures for human behavior models, developing extensible standards for describing/defining human behavior models, and determining when the conditions/circumstances where each model applies. Another key issue that the institute should address is the development of composable HBR data models and development of the means for storing data in a standard manner so that it can be reused across experiments. In addition to these prime issues, there are several secondary issues that the institute should address including support for collaboration and virtual meeting support, support for distance learning, and providing/supporting meetings/open forums at CGF/BR, ICCM, and other conferences in order to engage the research and military application communities and make them aware of the institute, its abilities, accomplishments, and community needs.

SAS-ET.V determined early in its effort that the concept to be pursued was that of a virtual institute as opposed to a virtual laboratory. The concept description in terms of an institute carries a broader connotation whereas a laboratory is connotes a narrower focus to the activity. In light of the broader focus of the virtual institute, an experimental testbed is a necessary component of the virtual institute. In addition, the institute would also have a number of other components, such as library and information and modeling clearing house. The institute would also provide training, an electronic library, a news center, and be a host for exercises and technology demonstrations. The institute would focus on addressing new areas of need in human behavior modeling for NATO, such as crowd modeling and joint training. The main structure of the institute, such as administration, technical support, management, and oversight would be relatively fixed whereas specific experimental topics and country participants would vary. This concept for operations and organization led to a flexible organizational structure for the virtual institute, as depicted in Figure A-1. Some portions of the institute continually exist, such as the operational executive, the administration function, and the Multi-national Control Board. These components of the organization provide guidance and oversight to experimental teams, aid in the formation of virtual teams, security, and aid in coordination between teams. The technical organization is another permanent part of the virtual institute; its purpose is to provide ongoing technical services to all teams, aid in interchange between teams, aid in making the technical connectivity needed by the virtual teams in order for them to exist, and also provide data storage, access, protection, data mining, and security and privacy services for the institute's data. The technical organization will assist the virtual experimental teams in managing and conducting their experiments and in placing their raw and analyzed data into permanent storage. These support organization exist to aid the virtual HBR experimental teams in executing their experiments and research. The experimental teams would have representatives from any interested member nation. The experimental team would have a well-defined research objective, such as the effect of organization on HBR, and when that objective is achieved that team can disband. Intriguingly, the experimental team can gain or lose members at any time and the team need never meet in order for it to conduct its research; it is the responsibility of the technical organization to insure that the distance between members does not interfere with their progress on their research.

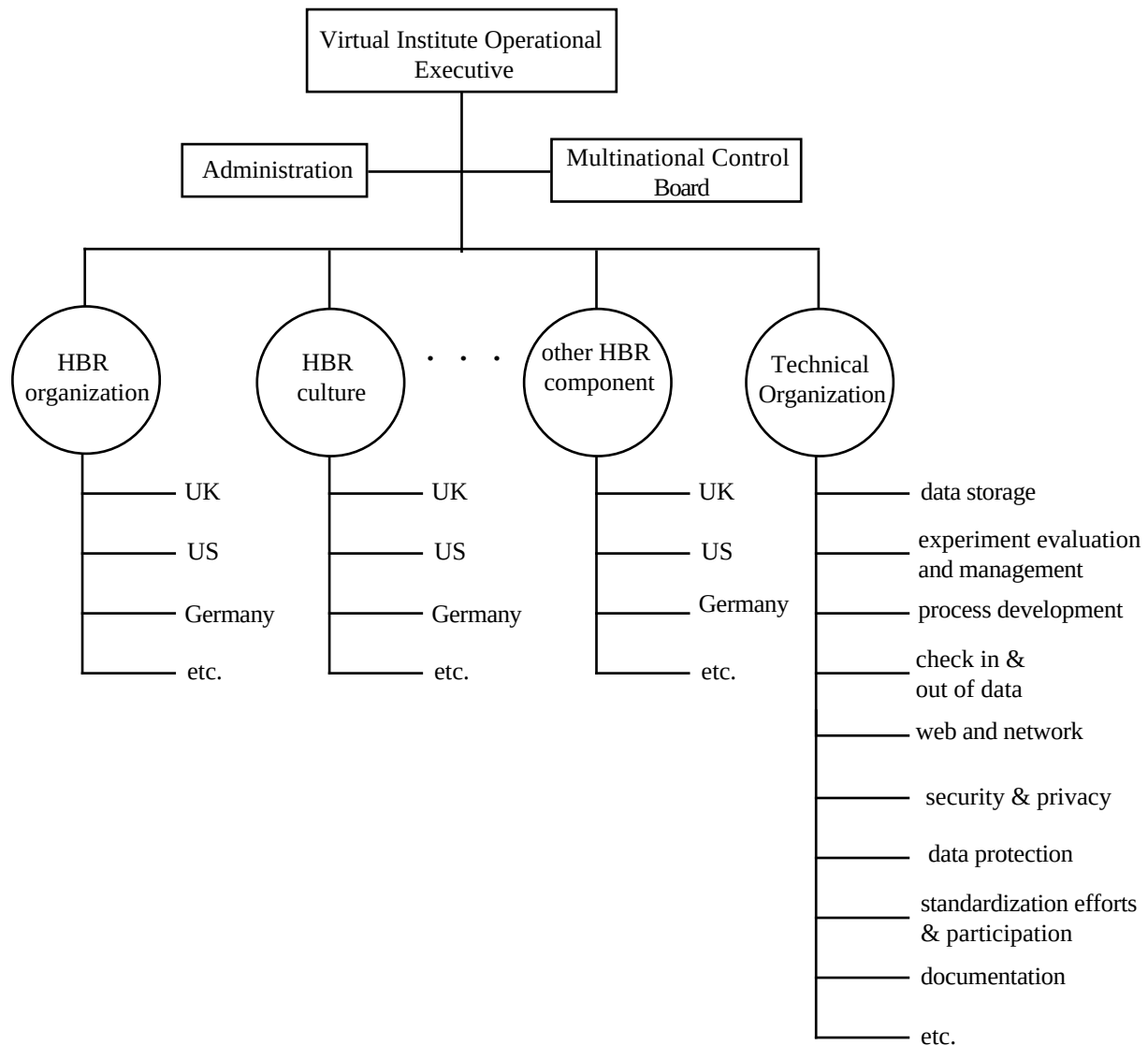


**Figure A-1: Virtual Institute Definition and Organization.**

Based on the described requirements above, the team constructed a concept diagram of the operational and process elements necessary for the virtual institute. This VI operational concept diagram is shown in Figure A-2 – Figure A-5. The key element of operation for the virtual institute is the experimental team, therefore, all of the virtual institute’s main processes are intended to help the experimental teams achieve their objectives. Once a HBR need is identified, a team is formed and the team begins its activities by identifying available resources and models, developing an experimental plan to expand the available HBR, and evaluating the end-product HBR. In general, processing proceeds from identification of national capabilities and needs to experimental definition and resource identification and development to experimentation, to evaluation, to feedback. Figure A-2 shows the part of the process related to cultural modeling. This portion of the process calls for the identification of national capabilities in HBR that are relevant to an experimental team. Once the national capabilities are identified, ontologies based on the national capabilities are formed and combined into a single common ontology for the experimental team. In parallel, national HBR libraries are identified; these libraries are combined by the technical organization into a virtual common HBR library. In addition to identifying the national capabilities, culture specific organizational behavior models are identified and both the national capabilities and organizational behavior models are represented commonly possible using, for example, the Unified Modeling Language

(UML). At this point, an initial common HBR for the experimental team has been formed. In parallel with this effort, a research plan and strategy to verify and validate the model and to extend the model to meet specific needs is undertaken. This items are presented to the virtual institute for examination and a determination whether the experimental team can proceed.

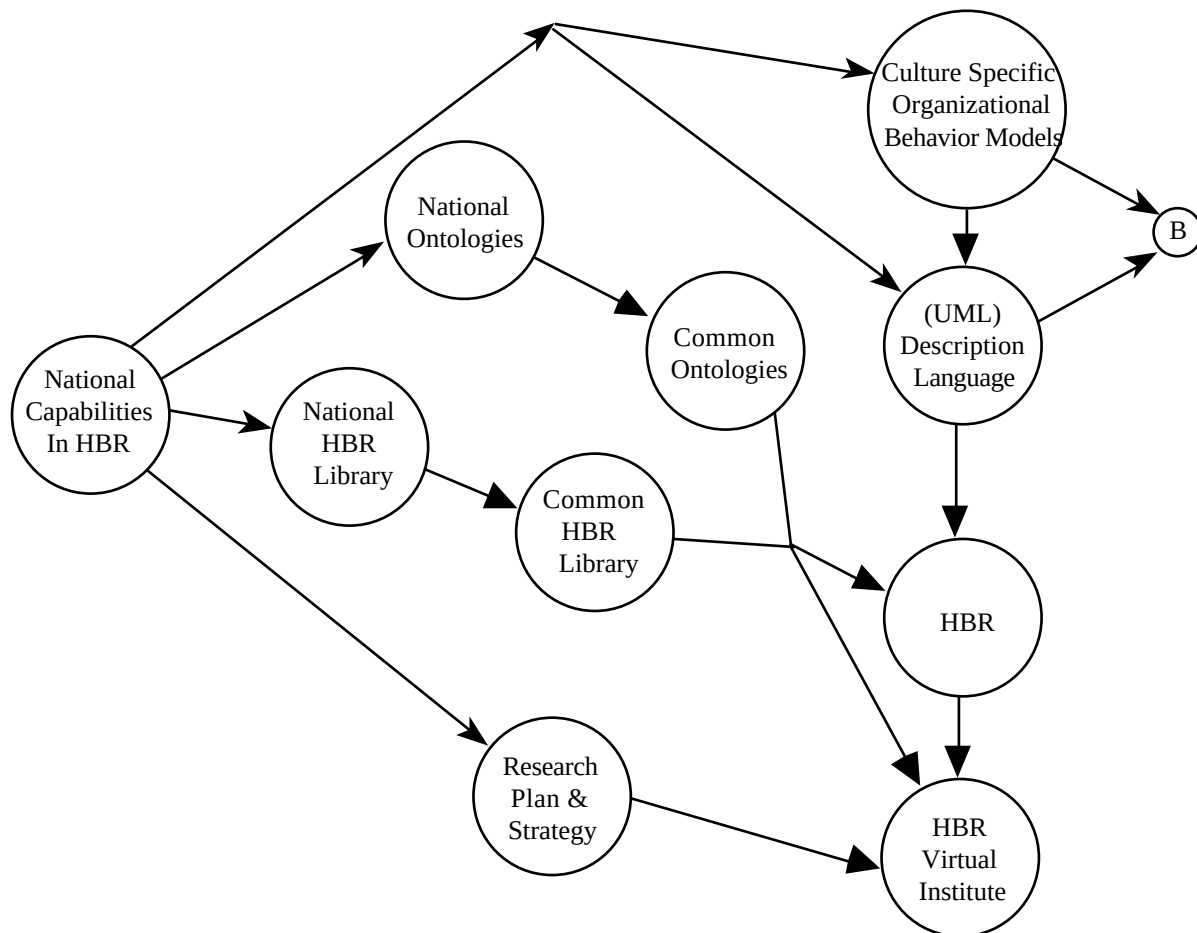


Figure A-2: HBR Virtual Institute Model Development Process.

Figure A-3 contains our best estimate of the process that the virtual institute should employ for experimental planning. As with model development, the process begins with the identification of available national capabilities and guidelines for sharing data between various members of the experimental team (some new guidelines may be needed from time to time as conditions warrant). In addition to determining the guidelines for sharing, the cost share for each member is determined. Finally, an assessment of key technologies is completed so that the team will know which technologies can be employed to achieve their research objectives. With these four items in hand, a research plan and strategy is developed and then an experimental plan along with experimental success criteria are developed to support the research plan. In parallel with this effort, the virtual institute support structure conducts an examination of the state of the technological art needed by the experimental team, assesses technical requirements for the team, and develops some technology as required. The key technologies, research plan, experimental plan, virtual institute technology assessment, and information from related assessments in the model development process are then combined and evaluated by the virtual institute. If the modeling effort and experimental plan warrant and the technology exists to conduct the experiment, the virtual institute allows the experimental team to move on to the next phase of the process, depicted in Figure A-4.

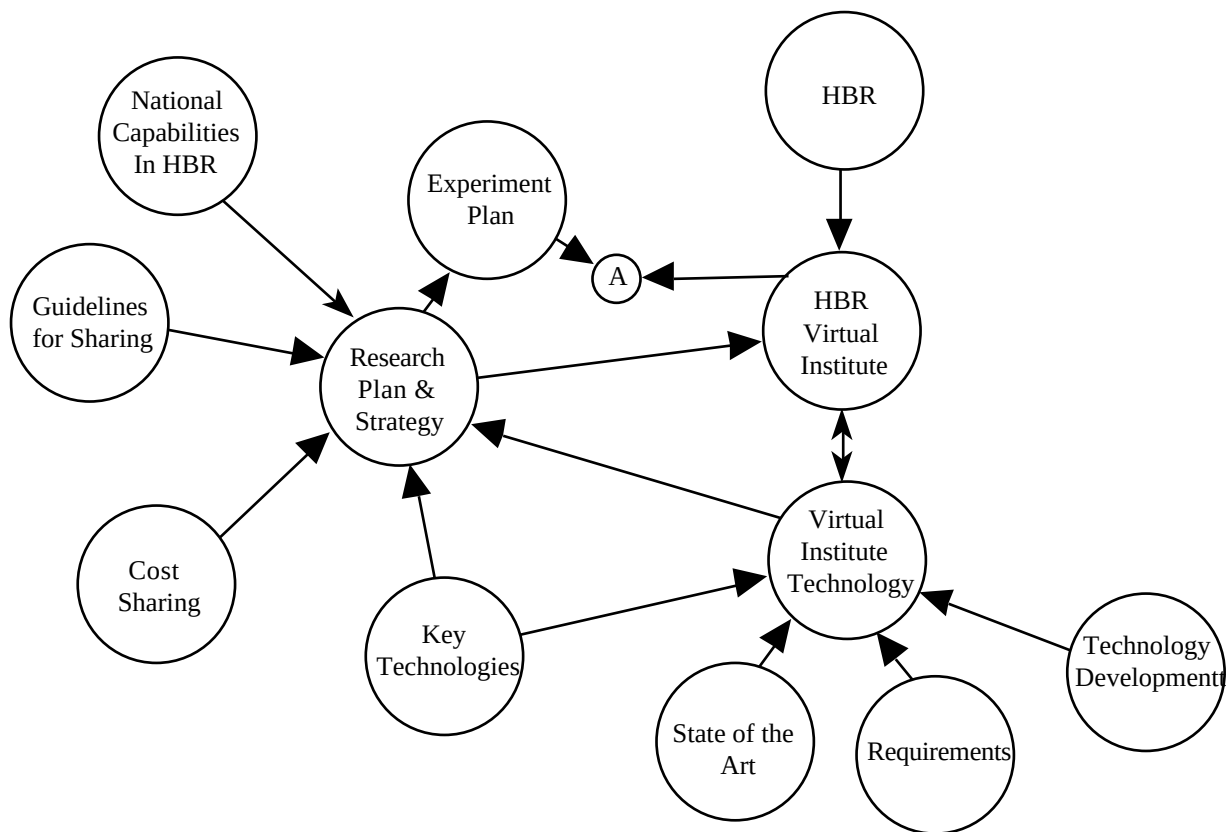


Figure A-3: HBR Virtual Institute Experimental Planning and Support Process.

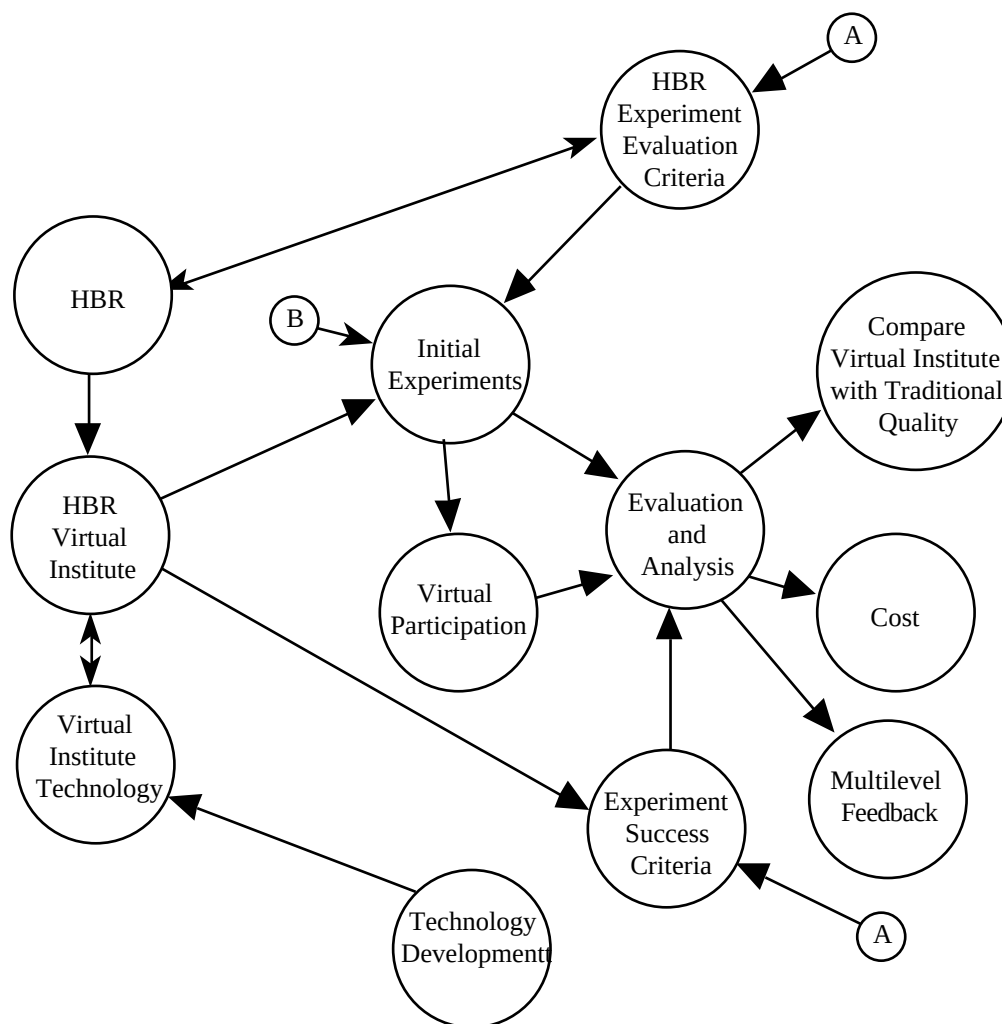


**Figure A-4: HBR Virtual Institute Experimentation and Evaluation Process Flow.**

The experimentation and evaluation process begins with the model data, experimental plan, research strategy, and technological underpinnings identified by the virtual institute. The first step is to conduct the initial experiments using virtual participants as necessary and available. The results of the experiments are evaluated and analyzed using previously determined evaluation criteria and experiment success criteria. As part of the effort to demonstrate the utility of the virtual institute, the quality of the results obtained using a virtual experimental team would be compared with a “real” team and the cost of the virtual and real approaches would be compared. As in all good scientific endeavors, we plan to have feedback from the results of the experiments and analysis into the earlier portions of the process in order to improve them. For the sake of clarity, these feedback arrows were omitted from the figures but, in our view, feedback can arise from any point in the process and go to any point in the process. Figure A-5 shows the complete process, with duplicate steps removed so that the process is indicated as clearly and cleanly as possible. One of the first activities for the follow-on organization should be to test and evaluate this process and determine where it can be improved.

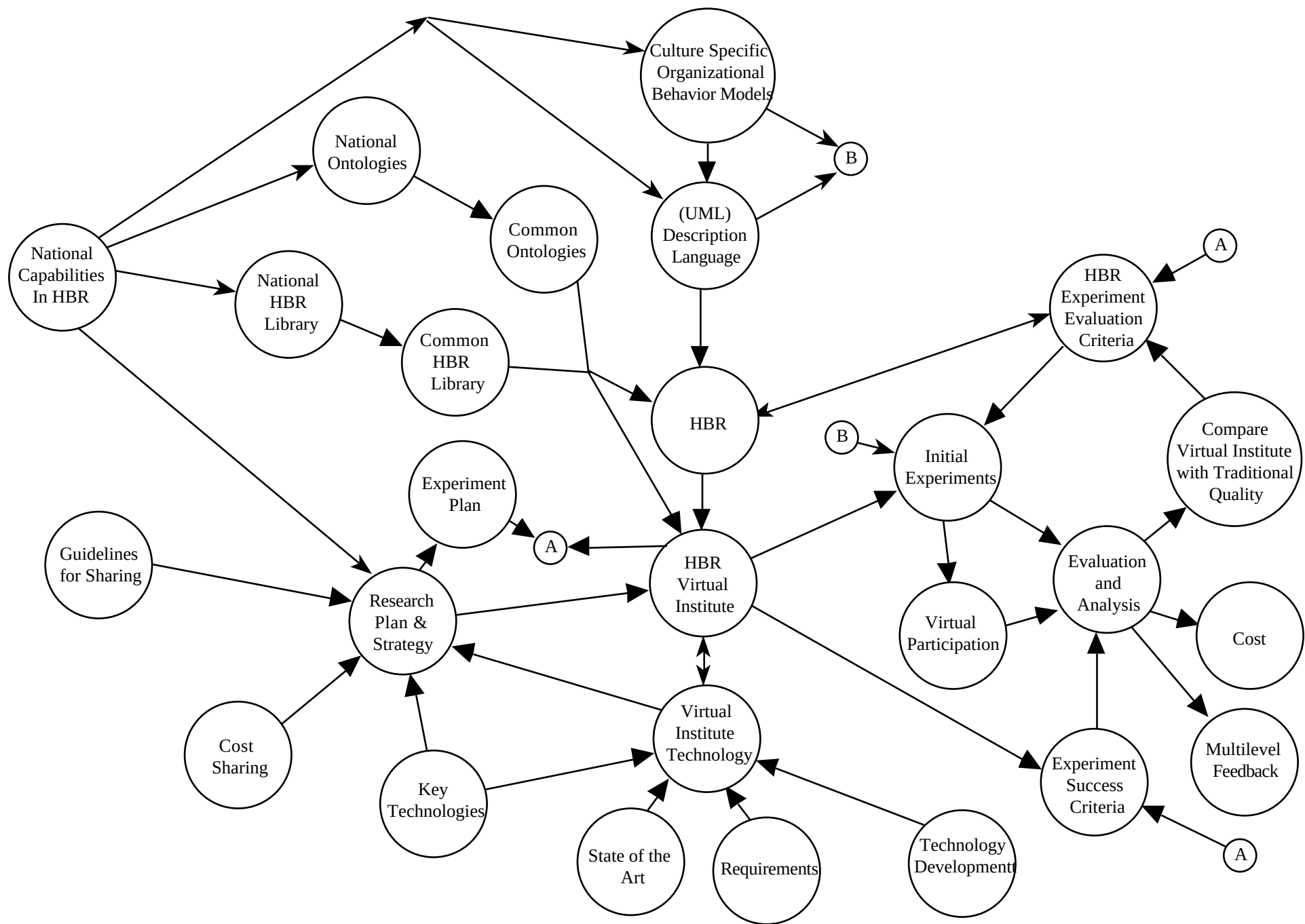


Figure A-5: Complete HBR Virtual Institute Process Flow.

To conclude, in the next section we present the recommended way forward for the implementation of a Virtual Institute for HBR in NATO.

## **A.4 WAY FORWARD FROM ET.V**

Based upon the meeting results and investigations conducted by the ET.V team, the SAS-ET.V team recommends that a RTO Task Group (RTG) be established to develop a demonstration Virtual Institute and that the Virtual Institute should produce a Research Plan for Team, Group, Organizational, and Cultural Modeling Research.

The ET.V has developed a preliminary Technical Area Plan (TAP), Draft Terms of Reference (TOR), and Program of Work (POW) for follow-on RTG to proceed directly into Prototype Virtual Institute implementation.

Based upon work done to date, SAS-ET.V has additional Recommendations for Virtual Institute use and administration. These recommendations follow.

SAS-ET.V recommends that one of the first tasks that the RTG should undertake is drafting a Memorandum of Understanding (MOU) to address intellectual property rights, government interests, funding, cost sharing, results sharing, handling of security and classification issues, management, commercial support and other issues to be addressed as part of international agreements. The MOU is an important first step in the development of the virtual institute concept because it will lay the groundwork for the scope of the virtual institute and insure the protection of the technologies made available to the virtual institute by the participating countries.

Based on our experience and research to date, the SAS ET.V makes the following three recommendations that should be undertaken to assemble, test, and validate a Prototype Virtual Institute and thereby demonstrate its utility and also test the process flow and organizational structure. The prototype would be able to handle one project at a time, unlike multiple parallel projects in the desired virtual institute but the prototype would serve to validate the concept and determine the utility of the results without making a great funding or manpower investment. As a first step, we recommend the development of a common ontology(s) and common interface between models for a single experiment that can be conducted to demonstrate the value of the virtual institute concept and also show that valid human behavior results can be obtained using a virtual institute. This suggestion closely mirrors the virtual institute process flow presented above, but differs in the fact that only one program would be executed and so there would be no need for cross-project communication or collaboration. The second step, much as in the proposed process flow, would be the development of use cases in order to demonstrate the utility of the virtual institute concept. These use cases would be derived from operational needs and the operational environment and would be written to address an operational need via experimentation using the virtual institute. Here again, we would concentrate on one project and be sure that it is a project suitable to the institute's abilities and can serve as a useful demonstration of its capabilities. The third step would be to develop a series of sequential projects, derived from these use cases that can be used to demonstrate and evaluate the complete virtual institute process and organizational structure without having to deal with the complexities of multiple projects or multiple HBR objectives being pursued within the institute simultaneously. When these demonstration projects are successful, a decision can be made concerning whether to develop and deploy a complete virtual institute.

An additional recommendation of SAS-ET.V is that the RTG improve cooperation between the HFM, IST, and SAS Panels, the NMSG, and NC3A to support the RTG in its development and demonstration of a broad-scale NATO virtual institute capability. To achieve this goal, SAS-ET.V recommends cooperation and coordination with other interested (and necessary) Panels to participate in the RTG for the VI. In our view, HFM interest would be in cooperation for the HBR technical aspects, IST interest would be in cooperation for the virtual institute infrastructure aspects, and SAS interest would be in cooperation for the concept

definition, integration, and exploration aspects. In addition, work must be performed in conjunction with SAS for operational analyses support and NMSG interest would be in cooperative use of many of the HBR developments in the M&S arena.

One area of clear importance to the Virtual Institute that remains to be addressed is increased participation by the member countries in various projects – we are still in need of more proposed projects and support from at least one defined and funded project to be included as a test participant in the HBR VI prototype. These projects, proposed and existing, from each participating country will be included in the prototype NATO VI and become the foundation for the exploration of the NATO VI concept which will lead to a recommended design and development process for a VI for HBR and for virtual institutes for the other six Panels.



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## **Annex B – PAPERS AND PUBLICATIONS**

The following papers/publications were written discussing the topic of SAS-053.

- 1) Banks, S.B., Stytz, M.R., Dompke, U. and Sutton, J. “Experimentation within the NATO Virtual Institute for Human Behavior Representation: A Process to Enable Multi-National Cultural Research”, *Proceedings of the Fall 2006 Simulation Interoperability Workshop*, Orlando, FL, 11-15 September 2006, pp. 341-350.
- 2) Banks, S.B., Stytz, M.R., Dompke, U. and Sutton, J. “Extending Multinational Cultural Experimentation Through Use of a Virtual Institute for Human Behavior Representation, *SimTecT 2006 Conference: Advancing Simulation Technology and Training*, 29 May – 1 June 2006, pp. 233-238.
- 3) Banks, S.B., Stytz, M.R. and Dompke, U. “The NATO Virtual Institute for Human Behavior Representation: A Mechanism for International Cooperation”, *Conference on Behavior Representation in Modeling and Simulation (BRIMS)*, Washington, DC, 17-20 May 2004, on CD-ROM.



| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                         |                           |                                        |
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| 1. Recipient's Reference                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2. Originator's References              | 3. Further Reference      | 4. Security Classification of Document |
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| 6. Title<br>Virtual Institute on Human Behavior Representation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                         |                           |                                        |
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| 14. Abstract<br><p>The research and development efforts across the field of human behavior representation are extremely varied and incorporate significant bodies of work both in the United States and internationally. Remaining cognizant of the many human behavior representation development efforts, performing cost-effective research among and across the nations, utilizing prior and on-going research, and establishing cooperative research projects requires tremendous effort. This report focuses on a discussion of the concept, work, and progress of a NATO Studies, Analysis, and Simulation Team (SAS-053) whose objective was to assess the potential utility and define the concept of a virtual institute for distributed, joint scientific investigations in the human behavior representation area, where the initial mission of the virtual institute is to develop a research plan for modeling military-related teams, groups, platforms, and organizations. The virtual institute concept provides an essential mechanism for ongoing information exchange across the NATO nations. SAS-053 also documented the current state-of-the-art in team, group, and organizational behavior and provided examples of multi-national research efforts. SAS-053 progressed both the state of team, group, and organizational human behavior research and the capability of NATO to use virtual technology to enhance research capabilities.</p> |                                         |                           |                                        |





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