RTO-EN-017
AC/323(SAS-032)TP/26

RTO-EN-017

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

BP 25, 7 RUE ANCELLE, F-92201 NEUILLY-SUR-SEINE CEDEX, FRANCE

RTO LECTURE SERIES 222

Simulation of and for Military Decision Making

(La simulation des prises de décisions militaires en vue de leur amélioration)

The material in this publication was assembled to support a Lecture Series under the sponsorship of the Studies, Analysis and Simulation Panel (SAS) and the Consultant and Exchange Programme of RTO presented on 15-16 October 2001 in Rome, Italy, 18-19 October 2001 in Stockholm, Sweden, 23-25 October 2001 in Virginia, USA and on 10-11 December 2002 in The Hague, The Netherlands.

Published June 2003

Distribution and Availability on Back Cover

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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 cooperative 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 coordination 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 coordinates RTO's cooperation 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 initial cooperation.

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 Studies, Analysis and Simulation 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 cooperation 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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Published June 2003

ISBN 92-837-1085-1

ST JOSEPH OTTAWA/HULL

Printed by St. Joseph Print Group Inc.
(A St. Joseph Corporation Company)
1165 Kenaston Street, Ottawa, Ontario, Canada K1G 6S1

Simulation of and for Military Decision Making

(RTO EN-017 / SAS-032)

Executive Summary

The current NATO-environment with reduced forces and decreasing military budgets, but new military tasks and types of operations, calls for the need to co-operate between services as well as between nations, and for new concepts and systems. NATO and Nations need adequate means to explore future military environments. The rapid acquisition of advanced technology by our adversaries will require us to develop dramatically new capabilities, likely based on information intensive systems. In turn, new doctrines will evolve whose forces structures and command structures are different than today's. New types of military operations are expected to become more common; for example, out of area operations, shorter preparation time, and involvement with the non-NATO PfP nations. The support of the Military Decision Making during operations is a vital need.

Modelling and Simulation (M&S) can be used as a tool to support the development and operational use of new concepts and systems for the future. M&S also help to better train and use existing forces and equipment and to improve operations in the new environment. The simulation of the Military Decision Process is a critical part in the use of M&S for this purpose.

Computer Generated Forces (CGF) and Human Behaviour Representation (HBR) can be used as a tool to support the development and operational use of new concepts and systems for the future. They also help to better train and use existing forces and equipment and to improve operations in the new environment. Emerging technologies will have a great impact on the implementation and on the military use of such CGF and HBR in the future. It offers support in different application areas; examples are thinking automated opposing forces (training and exercise), closed simulation systems (defence planning), Decision Support Tools (support to operations), and virtual environments (acquisition). The use of such systems will have great military implications and will save money and personnel in the future.

The aim of this Lecture Series is to provide an overview on the use of M&S of the Military Decision Process in the different application areas of training and exercising, support to operations, analysis and acquisition, and to provide a review of the state-of-the-art in the respective areas. These lectures are especially appropriate for scientific researchers and engineers involved in the development and use of M&S tools.

The material in this publication was assembled to support a Lecture Series under the sponsorship of the Studies, Analysis and Simulation (SAS) Panel and the Consultant and Exchange Programme of RTO presented on 15-16 October 2001 in Rome, Italy, on 18-19 October 2001 in Stockholm, Sweden on 23-25 October, 2001 in Norfolk, USA and on 10-11 December 2002 in The Hague, The Netherlands.

La simulation des prises de décisions militaires en vue de leur amélioration

(RTO EN-017 / SAS-032)

Synthèse

La situation actuelle de l'OTAN qui est caractérisée par des forces réduites et des budgets militaires en diminution, mais aussi par de nouvelles missions militaires et de nouveaux types d'opérations, nécessite de faire appel à une coopération non seulement entre forces armées mais aussi entre pays, ainsi qu'à des concepts et des systèmes nouveaux. L'OTAN et ses pays membres ont besoin de moyens adéquats pour étudier les environnements militaires futurs. L'acquisition rapide de technologies avancées par nos adversaires nous oblige à développer de façon urgente de nouvelles capacités, vraisemblablement basées sur des systèmes à forte intensité d'information. A leur tour, de nouvelles doctrines seront développées dont les structures de forces et de commandement seront différentes de celles d'aujourd'hui. On s'attend à ce que de nouveaux types d'opérations militaires deviennent plus courants; par exemple: opérations hors-zone, délai de préparation plus court, et participation de pays PpP non-OTAN. Le soutien de la prise de décisions militaires pendant les opérations est un élément indispensable.

La modélisation et simulation (M&S) peut servir d'outil de soutien pour le développement et l'utilisation opérationnelle de nouveaux concepts et systèmes dans le futur. La M&S contribue aussi à mieux former et à mieux utiliser les forces et les moyens actuels et à améliorer les opérations dans le nouvel environnement. La simulation du processus de prise de décisions militaires est un élément essentiel de la mise en œuvre de la M&S à cet effet.

Les programmes de forces créées par ordinateur (CGF) et de représentation du comportement humain (HBR) peuvent être utilisés comme outil de soutien pour le développement et l'utilisation opérationnelle de nouveaux concepts et systèmes dans le futur. Ils contribuent aussi à mieux former et à mieux utiliser les forces et les moyens actuels et à améliorer les opérations dans le nouvel environnement. Les technologies naissantes auront un impact important sur la mise en œuvre et l'utilisation militaire de ces programmes CGF et HBR dans le futur. Ceux-ci permettent un soutien dans différents domaines d'application; par exemple, les forces adverses automatisées intelligentes (entraînement et exercices), les systèmes fermés de simulation (planification de la défense), les outils d'aide à la décision (soutien des opérations), et les environnements virtuels (acquisition). L'utilisation de ces systèmes aura d'importantes implications militaires et permettra de faire des économies d'argent et de personnel à l'avenir.

Ce cycle de conférences a pour objectif de faire un tour d'horizon sur l'utilisation des outils M&S pour le processus de prise de décisions militaires dans les différents domaines d'application: entraînement et exercices, soutien des opérations, analyse et acquisition, et de faire le point des connaissances dans ces domaines respectifs. Ces conférences sont plus particulièrement destinées aux chercheurs et aux ingénieurs impliqués dans le développement et l'utilisation des outils M&S.

Cette publication a été rédigée pour servir de support de cours pour le cycle de conférences organisé par la commission Etudes, Analyse et Simulation (SAS) dans le cadre du programme des consultants et des échanges de la RTO du 15 au 16 octobre 2001 à Rome, Italie, du 18 au 19 octobre 2001 à Stockholm, Suède du 23 au 25 octobre, 2001 à Norfolk, USA et du 10 au 11 décembre 2002 à La Haye, Pays-Bas.

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Theme 3: Human Behaviour Representation (HBR)

Annexes

Acknowledgements

The first Computer Assisted Exercise (CAX) in ACE took place in 1989 (ACE 89). This was the impetus for the NATO research and technology organization (at that time the Defence Research Group) to take a closer look at the military operational requirements for CAX, and subsequently at the technologies, architecture and layout associated with such events. One of the initiators of the Long Term Scientific Study (LTSS) on CAX was the scientific advisor of SACEUR Dr. Herb Fallin, who is now the Division Chief of the OR and Functional Systems Division at NC3A, which supports NATO exercises.

The simulation of military decision-making was identified as having a major role to play in CAX. Therefore the LTSS on CAX proposed to initiate an LTSS on Computer Generated Forces (CGF), their architectures and relevant technologies. The CGF technology was seen to have not only a use in CAX but also in other military areas such as support to operations. In a third LTSS Human Behaviour Representation, seen as a kernel technology for simulation of and for military decision-making, was investigated.

I would like to thank NATO RTO and especially the former Panel 1 and now SAS-Panel for their interest in this work. They made it possible to bring a team of experts together to discuss these technology areas and the associated potential military uses. I would also like to register my thanks to the nations for supporting this activity (especially Germany for taking the lead in this research and enabling me to chair these LTSSs).

This Lecture Series would have been impossible without participation in the LTSSs of all the experts from the different nations and the NATO commands. I would like to thank all of them for their supreme contributions. Also I would like to thank all the hosts of the different meetings we have had during the conduct of the LTSSs for their excellent support and their hospitality. In particular thanks are due to the ISL in Saint Louis, France, the IDA in Alexandria, USA and the Air Force Agency for Modelling & Simulation in Orlando, USA as hosts of the Multinational Exercises.

The Lecture Series was held in

- Rome, Italy at the Joint Operational Headquarter (JOHQ)
  Point of Contact was LTC Lillo.
- Stockholm, Sweden at the Swedish Defence Research Institute
  Point of Contact was B. Backstrom.
- Norfolk, VA USA at the Virginia Modelling, Analysis and Simulation Center (VMASC)
  Point of Contact was Dr. R. Willis.

Many thanks to the nations and the institutions who hosted the Lecture Series. All Point of Contacts did a very good job and their support to the Lecture Series was excellent.

Many thanks also to RTA for the organization and the preparation of the educational notes. Jane Brooks from RTA supported the Lecture Series team in an excellent manner.

Last but not least I'd like to thank all lecturers for their splendid work in preparing the notes and in giving their presentations.

Dr. Uwe Dompke
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Introduction

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NATO Modelling and Simulation (M&S) Orientation Course

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Computer Assisted Exercises - Background

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Military Operational Requirements for Computer Assisted eXercises (CAX) in NATO

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Summary

Training followed by exercises enables individuals and teams to acquire and perfect knowledge and skills. In addition exercises provide an opportunity to acquire knowledge on strategies for the employment of newly acquired skills. However the ability to measure knowledge and skill acquisition decreases with the complexity of exercises. From a NATO perspective various types of exercises involve one or two echelons of command and focus primarily on the employment of joint and combined forces in a wide spectrum of operations. To exercise effectively a combination of simulation, data, mediation software and personnel is required. It is necessary to invest in the development of a CAX support team to ensure that suitable simulations are selected and that they are employed effectively. Configuring the data required by simulations and the measures of performance that can be collected for exercise control and analysis purposes, can also be supported by this team. Training of augmentation personnel needs to be incorporated in the exercise preparation process. Finally the necessary support needs to be provided to ensure that headquarters can employ their regular command and control systems. C2 capabilities must be initialised with data that is consistent with the exercise setting, they receive must regular stimuli in the form of messages of sensor input and their formal tasking should transmitted as efficiently as possible to the exercising environment.

1 Introduction

Requirements for computer assisted exercises can be derived from the various types of exercises that are conducted in NATO and from the operating environment that can be sustained in NATO to prepare, conduct and analyse such exercises.

Within NATO, the concept of training and exercises includes three different phases of knowledge acquisition that applies to groups and single individuals, namely instruction, training and exercising. Without specifying detailed definitions of these terms, we can state that instruction refers to the acquisition of skills by an individual or group for the first time. Instruction is followed by training, which is aimed at improving the performance of individuals and teams at employing their newly acquired skills and knowledge. Exercises can be conducted after effective training has taken place. In general terms, there are three specific goals that can be achieved through exercising. Firstly, exercises can be used to maintain skills acquired during training at a specified level of performance. Secondly, exercises can enable teams and individuals to generalise their knowledge by being exposed to a wide variety of situations. Finally exercises can be used to develop the knowledge about the conditions in which to best use specific skills i.e. which strategies to apply in which situations. This last aspect is also referred to as the development of meta-knowledge.

In the progression from instruction to exercises, the environment that is used to achieve the transfer of knowledge becomes more complex and the understanding about the use of the transferred knowledge increases in the team or individual. Hence exercising environments are the most complex and therefore require formal representations, which are typically well suited to automation. A major contributing factor to the level of complexity is the degree to which the quality of knowledge transfer can be assessed by measuring the performance of the individuals or teams involved in instruction, training and exercising. While performance

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measurement can be specified and executed well in instruction, it becomes increasingly difficult in training and appears to be ill-specified in exercising. However the quality of knowledge transfer is directly related to the capability to measure performance and must therefore be addressed and supported. Extensive instrumentation of the exercising and working environment is required.

In the new security environment that has emerged over the past ten years, the structure and composition of the armed forces in many NATO nations has changed considerably. In particular, many nations have transitioned from an army based on conscription to fully professional armed services. This new form of organisation relies on many persons joining the ranks of the armed forces for short-term contracts. However the sustained economic growth in most nations has made it difficult to attract suitable people. This effect is compounded by the considerable amount of highly skilled and experienced professionals that have left the armed forces. Therefore the need for a sustained training and challenging exercising environment that provides a consistent level of knowledge transfer, has become even more pressing.

When considering the general context of exercises, we also need to note that many operations are conducted on an “ad hoc” voluntary participation basis by nations. These many often small-scale commitments place a considerable and sustained demand on limited personnel resources. Since planning for these operations cannot be foreseen and incorporated in planned training and exercise events, the training environment must be highly configurable and composable to include relevant elements in order to prepare personnel participating in these operations effectively. Furthermore, good performance measurement is required to establish the ability of the personnel to carry out their tasks in an often highly visible environment from a political and media perspective. These inherently multi-national operations almost invariably involve non-NATO personnel who are unfamiliar with NATO tasks and procedures and need to be trained and exercised to work together in an effective manner.

Co-operation with non-governmental and private volunteer organisations has also increased considerably. Since military forces are often responsible for the overall security in the area and for the protection of local populations as well as external organisations, the representatives from these organisations also need to be trained.

Furthermore, it should be noted that a new problem is emerging as a result of the many parallel operations that are being conducted by forces from NATO nations. Due to the length of these commitments, it is becoming increasingly difficult to ensure that military personnel is trained on the full spectrum of tasks that they are expected to be able to deal with. Therefore, training and exercising is required whilst personnel is deployed and will need to be inherently distributed.

Overall there is a greater need for training and exercising environments that can be configured rapidly and made widely available to a broader community of people requiring their skills to be developed in a planned and consistent manner. Also there needs to be greater emphasis on a verifiable level of skill in personnel because the room for error has become extremely small due to the high degree of media coverage and to the stringent and detailed political guidance.

2 Classes of Computer Assisted exercises in NATO

Recently NATO has revised its training and exercise strategy and has identified two main classes of exercises as requiring extensive computer assistance in their exercises. These so-called level 2 and level 3 exercises are regularly scheduled exercises that involve two echelons of command. The actual focus is always on the lowest echelon that participates. Indeed the time required by the lowest echelon to perform its command and control cycle cannot be compressed and constitutes a delay for the highest echelon to receive feedback. Level 2 exercises involve the regional, joint sub-regional and component command headquarters. Level 3 exercises include joint sub-regional and component command headquarters as well as national or multi-national formation headquarters. For both types of exercise, the force composition depends greatly on the ability of headquarters to participate as response cells. Indeed, exercises can only be successful when the information flow that surrounds the headquarters can be simulated to an extent that is sufficient to make part or whole of the headquarters perform its functions. Response cells, which represent the subordinate force headquarters, are critical to the implementation of the external information flows of a headquarters.

In preparation for many level 2 and 3 exercises, headquarters conduct individual and collective training events. If possible, headquarters would like to apply the same computer assisted environment and scenario that is utilised in the multi-headquarters exercise that they are working towards. The type of application that is required is twofold, namely the generation of a set of information stimuli and the conduct of small-scale simulations. In the first case, headquarters exercise planners should be able to generate an information flow from the simulation environment that can be used to stimulate selected headquarters functional areas. By executing limited simulation runs in which exercise planners perform all the functions of the exercise components and generate a consistent flow of information over time. The collected set of messages and situation snapshots can subsequently be replayed and injected into the headquarters for selected sections. The objective is to train sections into the procedural execution of their functions. It is essential to conduct such exercises in view of the regular rotation of personnel. Having concluded the procedural training satisfactorily, small-scale headquarters exercises can be organised during which headquarters personnel perform some of the exercise control cell functions. The dynamic nature of the training enables the staff sections to perform complete command and control cycles and to interact with other sections, thus enabling internal headquarters processes to be tuned effectively. Obviously these additional exercise generation requirements can only be facilitated if headquarters have access to a simulation capability that can be executed within their infrastructure and that can be managed within the available limited personnel resources. From a data set preparation point of view, they can benefit from the work that is conducted for the larger exercises or they can re-use paste exercises.

In addition to the regularly scheduled exercises, the NATO modelling and simulation master plan has identified the Combined Joint Task Force (CJTF) headquarters exercises as being able to benefit greatly from the application of simulation technology. In particular the ability to tailor the simulation environment through the application of emerging simulation interoperability frameworks is perceived as having great potential in building an effective training and exercising environment for the many different types of operations that a CJTF headquarters may be called upon to conduct in co-operation with many different force providers. Overall the requirements of CJTF exercises are comparable to those of regular NATO level 3 exercises although the emphasis may be placed more on the peace support operations aspects of the mission and participating forces will almost definitely include forces provided by non-NATO nations. Hence this type of exercise introduces the need to be able to address the representation of these forces in operations where civil and military co-operation issues are highly important.

Finally, NATO is in the process of establishing a training organisation that intends to make extensive use of simulation to perform its various training roles. The concept of the ACE Command and Staff Training Programme (ACSTP) centres on the ability to provide individual and collective training to headquarters according to a verifiable set of performance standards. The ACSTP requires a set of tools to design and implement training and exercise scenario’s that will create the conditions for headquarters to execute their command and control processes so that they may achieve prescribed performance standards on an individual and collective basis. The ability to collect sufficient data to compare individual and collective actions and results to normative measures will be essential in ensuring that the ACSTP meets its objectives.

As an overall constraint for the design of exercise and training environments, it should be noted that efficiency considerations mandate that scenarios should be re-used on an extensive basis. Hence the attraction of generic versus specific scenarios and particularly the use of generic forces and structures. However experience has shown that training benefits are considerably greater when applying realistic and representative forces and environments primarily due to the additional meta-knowledge that is acquired by the subjects of training and exercises.

As discussed above, the implementation of a headquarters external information flow requires the availability of teams of personnel, which represent organisations that the headquarters would interact with. In addition to the headquarters subordinates, these cells typically include:

(1) A higher headquarters cell representing the headquarters that command the exercising headquarters

(2) A host nation support cell representing the various nations that are part of the scenario and that provide logistic and legal interaction to the headquarters

(3) A non-governmental and international organisations cell

(4) A media cell

(5) Other forces cells, which represent the other parties, that play an active role in the scenario. Other forces may entertain amicable or belligerent relationships with the headquarters or may be considered as neutral.

These cells need to be able to interact with the headquarters in the manner that would be realistic for them. This implies the usage of doctrinal communications and information systems assets, commercial communications means as well as all forms of open media expression.

3 Joint Operational Level Mission Requirements

Within the context of a joint operation, the mission of the joint headquarters is to co-ordinate the actions of various component commanders. In general terms, this will entail that a land mass is secured that is part of the theatre of operations and that constitutes the focus of ground operations, that an associated air space is suitably controlled and that similar conditions are created in a specified maritime area. In particular, the complementary use of force capabilities is the focus of the joint aspect of planning and execution. The types of missions that a joint headquarters will expect its Land Component Commander (LCC) to perform can be summarised as including:

(1) Disaster relief and humanitarian aid: this would entail the provision of a secure environment on land for the conduct of:

  (a) food distribution,

  (b) medical care,

  (c) engineering support,

  (d) return of displaced persons,

  (e) civilian activities ensuring the return to an organised and law abiding society e.g. elections

(2) Peace keeping: within the context of an approved operation in a sovereign state, the LCC would contribute to the stability of the situation by projecting sufficient military presence to discourage unwanted organised violent actions by factions within the nation or by other nations. This type of mission would most probably be combined with a number of aspects described under the aspect related to humanitarian relief due to the likely degradation of local security, provision of community resources and breakdown of infrastructure.

(3) Peace enforcement: establishment through military means of a secure environment to implement the political rationale that led to the conduct of the operation. Such an operation would typically involve various unfriendly factions and a state that does not agree to the military intervention. Although assumed of limited scale, this kind of operation may cover the entire spectrum of military actions.

(4) Protection of the integrity of the NATO nations territory: still the primary mission of the headquarters of the alliance, these types of operations would probably involve the massive use of alliance military power to restore the territorial integrity of the alliance. Although the likelihood of such an operation appears relatively low at this time, headquarters need to be capable of managing the complexity that would be involved with the massive use of military force.

For air matters, the Joint Force Air Component Commander is responsible for the provision of air support in terms of protection of air space from any violent opposition, air reconnaissance, transportation of personnel, equipment or food and support by ground offensive-capable aircraft. Due to the high degree of technological sophistication of the aircraft, weapons and sensors employed by the air force, a relatively higher degree of fidelity needs to be achieved in the representation of these assets compared to land forces.

For maritime matters, a maritime component command would be expected to be able to perform tasks like ensuring the security of ports that are used by maritime forces or commercial shipping bringing resources to the area, guaranteeing the control of specified maritime areas or carrying out the implementation of sea embargoes, etc. Any amphibious operations that could be complementary to the activities of the Land Component Command would also be expected to be managed by the maritime component or by a specific marine command in close co-ordination with land and air components. From a joint perspective, the representation of amphibious operations requires the environmental conditions to be suitably selected to portray issues of access and time required to perform a successful landing.

For logistic matters, co-ordination needs to take place to establish the arrival of forces, the requirements and provision of supplies, the capability to protect and maintain the equipment used by the force and the organisation of medical assistance.

For special operations matters, a specific component command would be tasked to address specific requirements for intelligence collection or specific detailed interactions with local entities. A high degree of fidelity needs to be represented to provide a reliable depiction of the teams and assets that are employed and tasked to conduct special operations.

4 Environmental Representation Requirements

The following environmental elements should be represented by a simulation capability in order to portray their impact on the entities involved in a simulation of a joint combined operation

(1) Terrain conditions that influence cross-country movement, maritime movement and potentially airborne operations, detection, transitions from sea to land and vice versa. Of particular importance are major obstacle features e.g. rivers, gorges, fjords

(2) Light conditions: day, night, transitions between night and day, fog, cloud cover

(3) Weather: wind, precipitation, temperature, barometric pressure, cloud levels

(4) Artificial environment elements: smoke

(5) Disease: type of effect on personnel and supplies (lethal or non-lethal, reduction of effectiveness over time), method and rate of transmission, average duration of disease

(6) Infrastructure:

- (a) Road networks
- (b) Railway networks
- (c) Power networks
- (d) Communications networks

(7) Urban areas

The impact of the environment could include the following aspects:

(1) influence on line of sight by terrain features, light conditions either natural or artificial

(2) mobility

(3) counter-mobility

(4) sensor effectiveness

(5) weapon effectiveness

(6) personnel effectiveness

(7) quality and usage of supplies

5 Force representation requirements

From a land component perspective, it may be necessary depending on the size of the allocated force to model individual battalions and companies. Due to the potential allocation of specialised units and their allocation from a contributing nation, units down to platoon level may require representation.

Units should be described as consisting of various types of personnel, a description of vehicles, combat systems, supplies and holdings, sensors, communications and information processing assets and other elements which contribute to the functioning of the unit e.g. mobile bridges, building equipment. In addition factors of morale and welfare of the units may be described. Unit leadership style, co-ordination and overall cohesion may also be included as descriptive characteristics.

From an air component perspective, the following air assets and activities need to be represented in a simulation environment that is used to support joint exercises:

(1) Airbases: should include local sensors, runway capability, parking capability, shelter capacity by type, local air defence assets, local ground defence assets

(2) Squadrons

(3) Pilots, crews or occupants of aircraft when they are in exceptional conditions e.g. after a crash or in a hostage situation

(4) Ground-based air defence assets

(5) Ground-based air search radars

(6) Air missions:

  (a) Offensive: against specific targets or target classes, orbiting or not

  (b) Defensive: orbiting or on base alert

  (c) Support missions: escort, suppression of air defence, air to air refuelling, reconnaissance (orbiting and others), electronic warfare, early warning, command and control

  (d) Transport missions

(e) Maritime patrol: either anti-surface or anti-submarine

(f) Packages: support mission providing protection and assistance to multiple principle missions.

From a maritime perspective, the following assets and activities need to be represented:

(1) Surface and sub-surface craft including carrying capacity, supplies, on-board squadrons, sensors, jammers, air defence assets, anti-submarine assets,

(2) Landing craft

(3) Amphibious craft

(4) River operations capable craft

(5) Marine units including ground capable forces, squadrons and support units

(6) Ships should be able to provide missile firing support on targets, to perform gunfire support, to facilitate the processing of land forces through ports, to conduct amphibious landings, to detect and affect air assets, to launch air missions and packages

From a logistics perspective, the following assets and activities need to be represented:

(1) Supply units either fixed or mobile, supporting other units with specific supplies using convoys of cargo trucks, tanker trucks, railway assets; barges or aircraft

(2) Maintenance units capable of transporting and repairing damaged equipment

(3) Medical transportation assets, field hospitals and fixed location hospitals and treatment facilities

(4) Medical personnel and teams available to perform specific activities

Special forces:

(1) Specialised units, which have the ability to remain highly undetectable, can perform special observation actions and damage-selected targets.

(2) Units can be inserted or extracted by aircraft, boats or other transportation assets.

The entities and objects described above should be capable of performing a relevant subset of the following functions:

(1) Movement functions

(2) Combat functions

(3) Fire support

(4) Air defence

(5) Search and rescue

(6) Engineering functions

(7) Communications functions

(8) Medical functions

(9) Intelligence collection and fusion functions

(10) Movement control functions

(11) Sustainment and maintenance function

6 Non-military entity representation requirements

The context of any military operation will require direct interaction with civilian entities and will result in exchanges of supporting elements. Therefore the civilian assets that can contribute to the operation or that are the subject of the operation need to be represented as active objects in the simulated environment. These objects include:

(1) Civilian transportation assets (land, air and maritime shipping)

(2) Movement control authorities

(3) Industrial production capabilities and their controlling authorities

(4) Power and fuel production and distribution authorities/entities

(5) Medical support and transportation capabilities

(6) Food and water production and distribution capabilities

7 Exercise Operational requirements

In order to provide operational utility for exercise purposes, the simulation environment that supports an exercise must meet the representation and functional requirements discussed in the previous sections. In addition, it must also allow the exercise planning staff to configure the environment within acceptable time lines and affordable resource requirements. It should allow the conduct of exercises with limited augmentation and support data collection to perform analysis and after-action-review.

7.1 Simulation selection

In view of the evolving requirements of headquarters concerning the aspects of the real world that they wish to exercise, exercise planners could greatly benefit from the ability to select and configure simulation environments to best meet the complete set of specific exercise requirements. A repository of simulations that are realistic candidates for exercise support would be required to facilitate the selection process. Simulations can be considered realistic candidates to support an exercise if they have been proven in previous exercises. More importantly though is the availability of organisations that can ensure their proper employment, the constitution of effective simulation data bases, the training of augmentation personnel and the necessary interaction between simulation and command and control systems. Indeed it should not be considered as a recommended approach to attempt to constitute this kind of capability within the planning cycle of an exercise. In this context, simulations can be either interpreted as single tightly organised simulation models or as combinations of simulations that are capable of inter-operating.

Should existing simulation environments not include all the desired functionality, exercise planners need access to a process that allows them to introduce requirements for new developments that are either part or can inter-operate with components that have been used successfully for previous exercises. In order to formalise this process, a repository of simulation modification requests needs to be available to register requests officially. An organisational entity within NATO needs to be appointed as the custodian of this repository. In close co-ordination with the NATO strategic commands, funding for modifications can be requested for the implementation of prioritised sets of modifications. This approach ensures a consistent development of simulation capabilities that are beneficial to a wide variety of exercise applications. The CAX management organisation should subsequently manage the implementation and test of the modifications. Furthermore it should perform the following roles:

(1) serve as the proponent for NATO of realistic simulation candidates for exercises

(2) develop and expand the NATO reference repository of simulation descriptions

(3) act as the advisor to headquarters in the simulation selection process

(4) in the case of federations of interoperable simulations, act as the accreditation authority for utilisation in NATO exercises.

Indeed, it must be recognised that it is necessary to invest in a team of experts to apply complex simulation environments effectively for training and exercises.

A final point that needs to be addressed is the need for the ratio between simulation time and real time to be able to vary between 0.01 and 60. Although exercise conduct will not require ratios of above 3 or 4 to 1, data base validation and test sessions will require much higher ratios to be completed in a cost-effective manner.

7.2 Data base preparation time and effort

Having selected a number of simulation environments that are realistic options to support training and exercise events, it is necessary to establish an environment to create and maintain descriptions of the entities described in sections 4, 5 and 6. The descriptions must be such that they can be transformed into suitable data for various simulation environments. In addition they must comply with any constraints and requirements that are imposed by the command and control system applications that are employed by the headquarters participating in associated exercises. Indeed the effectiveness of an exercise is directly dependent on the ability to employ the tools that staff would be required to employ to perform their mission. Since NATO as an organisation does not own forces and operates very few systems within its structure, most data needs to be provided through national channels. Hence CAX data management is an inherently distributed activity in a NATO context.

As discussed in the section 7.1, the simulation management organisation that needs to be constituted should also be given the responsibility to manage the data that is used to populate simulation environments that are used for exercises. The organisation should develop a process that ensures the verification and validation of data by the nations whose forces and capabilities are to be simulated. The necessary environmental data should also be gathered from national sources. Tools that support the distributed data collection effort as well as a robust and secure communications architecture are necessary to develop and maintain relevant data sets. In particular distributed access to simulation environments is necessary to enable data providers to validate the behaviour of representations in combination with specific simulation environments. Indeed it is not sufficient to verify the characteristics of entities in a static manner. The dynamic characteristics need to be verified also and compared to expected behaviours when interacting with the environment and with other entities. This form of testing can only be accomplished by accessing the simulation environments.

Once an exercise data set has been compiled, verified and validated, it should be suitably documented to enable augmentation personnel to be trained and to provide exercising headquarters with reference data. Several forms of documentation should be supported and formats should be flexibly configurable.

Finally data management tools should be available that enable the flexible re-use of data that has been developed for previous exercises either in part or in full. Considerable efficiency gains can be obtained in this manner.

Overall the process of designing, compiling, verifying and validating exercise data sets should be completed within a 6 to 9 month time frame.

7.3 Exercise control cell requirements

As discussed in section 2, a number of exercise control cells need to be formed to conduct an exercise. They include:

(1) Response cells representing the headquarters and forces that are subordinated to the exercising headquarters

(2) A higher headquarters cell representing the headquarters that command the exercising headquarters

(3) A host nation support cell representing the various nations that are part of the scenario and that provide logistic and legal interaction to the headquarters

(4) A non-governmental and international organisations cell

(5) A media cell

(6) Other forces cells, which represent the other parties, that play an active role in the scenario. Other forces may entertain amicable or belligerent relationships with the headquarters or may be considered as neutral.

These cells need to be able to interact with the headquarters in the manner that would be realistic for them. This implies the usage of doctrinal communications and information systems assets, commercial communications means as well as all forms of open media expression.

Obviously the size and composition of these cells should be as limited as possible to perform their function. As a general rule, the size of cell should not exceed 25 people and preferably be composed of less than 10 people. The profile of the personnel should be functional area experts. This requires the interfaces of the simulation and information exchange environments to be suitably designed to express their activities and information in a manner that is tailored to their specific professional backgrounds. Performing clerical activities such as re-formatting data either in textual or graphical form should be avoided.

In addition, the amount of training required to operate the simulation environment and to interact with the exercising headquarters should not exceed three to four days including the conduct of a mini-exercise. In order to achieve the most effective knowledge transfer, prospective augmentation personnel should be able to train on operating the simulation environment and the information exchange tools at their regular place of work. The final training phase could subsequently focus on acquiring a good understanding of entities that the cells will be managing, on the intended exercise flow and on the information flow that needs to be established with the exercising headquarters.

7.4 Exercise management support

A cell that was not discussed in the previous sub-section is the exercise management cell. The persons that make up this cell need to combine a profound understanding of the exercise objectives, of the courses of action that have been designed by the exercising headquarters, of the simulation environment that is being employed and of the simulation data sets that have been compiled to support the achievement of the objectives. Their principal mission is to monitor exercise progress and to identify and advise on any immediate or other important events that may cause the exercise to deviate from its intended path to such an extent that the intended objectives cannot be met.

In order to perform their mission, the intended flow of the exercise needs to be expressed in a manner that can be monitored during the execution of the exercise. Monitoring entails the ability to collect data from the simulation environment and combine it into aggregate measures. Depending on the objectives of the exercise, these measures may vary and in some cases they may be directly at the level of detail of the simulation environment. Hence the exercise management cell should be able to compose the measures and express how they should be monitored over time.

Examples of measures of performance that may require monitoring are:

(1) Force ratios for ground forces in specified geographical areas. Such ratios are combined with empirical knowledge to assess very rapidly what the trend of the exercise is and whether it is in line with the expected exercise flow. Should the actual trend deviate too much over time from the intended evolution, exercise directing staff may wish to capture the reasons for the deviation for after-action review purposes and may wish to introduce elements that may reduce the deviation without appearing to be artificial to the exercising headquarters.

(2) Attrition of high value assets for air and maritime forces. Given the many scarce resources that are employed in these forces and their potential to influence operations in a significant manner, any attrition needs to be reported and its causes identified. The directing staff must be able to make a timely assessment of the impact of the attrition on the course of the exercise and develop suitable courses of action from an exercise management perspective.

From the examples above, it may become clear that exercise management staff require the ability to monitor events and trends in a flexible manner. Just as important, is the ability to understand the reasons for them. Therefore detailed information about entity characteristics, exact situations and tasking need to be available to the directing staff in a real time event analysis environment. Combined with simulation expert support, the reasons for events can be understood and a truthful explanation for events can be presented to exercise participants at all levels. Indeed due to limited information that exercise participants in headquarters, response cells and exercise control cells may have about the complete set of data that has led to a situation, it is likely that their interpretation of trends and events may be incorrect. Therefore, t is essential for exercise management staff to be able to uncover the rationale for particular situations in a very short time frame.

7.5 Analysis support

In order to provide exercise control and after-action-review support, capabilities should be provided that enable the capture of selected status data and event data capture. The requirements described in the previous sub-section should enable the definition of those indicators that are considered important from an exercise analysis perspective. The ability to relate the indicators to exercise objectives and derived sub-objectives is also necessary in order to verify the completeness of the analysis effort.

However exercise analysis introduces an additional dimension. Indeed the environment used by the subjects of the training or exercise needs to be monitored also in order to gain a complete understanding of the problem solving cycle that exercising staff performs. Instrumentation of both the exercise driving and of the headquarters command and control environments is required to permit complete analysis of the command, control, execution and reporting cycle.

7.6 Real-world command and control system mediation

The previous sub-paragraphs will have shown an evident need for close integration between the exercise environment and the command and control (C2) systems used by exercising headquarters. Firstly, the command and control systems need to be incorporated into the exercise control cells at response cell and exercise management level. Secondly the systems need to be open for instrumentation and data collection by exercise analysis tools for assessment purposes.

In order to ensure consistency between the representation of the world in the simulation environment and in the C2 systems and to provide the equivalent level of information exchange that exists between real-world levels of interaction within C2 systems, it is necessary to support the following aspects of mediation:

(1) Initialisation: it is necessary to be able to transform relevant simulation data base data into the appropriate format that can be used by the C2 applications. This includes entity status, perception and relevant system characteristics data. If the exercise is set on artificial geography, the mapping characteristics should also be exportable from the exercising to the C2 environments.

(2) Reporting: in order to provide exercising staff with doctrinally correct responses from subordinate or equivalent headquarters that are not exercising, it is necessary to provide response cells with the ability to extract relevant data from the simulation environment to provide status or event updates. Typically this form of mediation will require subject data to be formatted into specific messages that comply with prescribed encoding standards or to be achieved by being able to update C2 databases. In addition it may be necessary to support the generation of sensor output data from the exercising environment. Standard sensor communication protocols will need to be supported to populate perceived situation displays effectively.

(3) Ordering: in some cases, C2 systems are employed by headquarters that allow plans and tasks for subordinates to be expressed in a sufficiently formal manner that they can be interpreted by automated tools. In order to conduct exercises in the most efficient manner, mediation software should be available to transform the plans and tasks into actions that can be executed by simulated entities without manual intervention.

Given that the aspects of mediation described above are feasible, it is necessary to ensure that the necessary measures are taken to respect security regulations that exist when operating in close integration with C2 systems.

A Definition

Computer Assisted Exercise

An exercise using computer models designed to place the command and control element of a headquarters in a realistic, stressful combat-like environment to stimulate decision-making, command and control staff interaction and coordination

Though this is a somewhat generic definition, it highlights the key elements that comprise a computer assisted exercise.

First is the creation of a simulated environment that can stimulate human decision-making. Computer are used to simulate forces and their interactions and also for presenting relevant information to the participants. Typically, this is the command and control information that flows to and from commanders and their staffs.

Second, the computer assistance appears in several ways. The computerized combat simulations are used in the exercise preparation phase to construct and fine-tune the basic scenario. During the exercise, computers are used to simulate those elements in the exercise that are not played by people or real equipment. The exercise controllers to monitor the events and initiate corrective actions. Once the exercise ends, computers aid the analyses.

Third, computers are used to create linkage, or a translation, between the information and databases that make up the simulated environment, and the information and databases used by real command and control systems.

Applications of CAX include both education and training. For training, the typical audience may be smaller staff groups with a focus on specific areas or functions. For exercises, there is typically a broader scope of participants and the focus in on the functionality of a major organizational structure. A key interest in the latter case is to activate the command and control structure for crisis or wartime scenarios.

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CAX System Architecture and Services

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Abstract

The architecture of CAX Systems can be seen from three different perspectives: the Logical or Functional Perspective, the CAX System Topology and the System Physical Architecture. Each of these different views with its different layouts will be described in the paper. A comparison of different CAX Architectural Options based on the functional architecture and assessment criteria such as User Satisfaction, Implementation/Operation & Maintenance Cost, Security, Technological Trends and Flexibility follows.

The trend in the development of complex software systems goes to the use of so-called services. This approach and services to be used in building CAX systems are described.

1 Introduction

The CAX Architecture is addressed here from three perspectives:

The **Logical or Functional Perspective**. This view focuses on the logical or functional interrelationship of the CAX System Components and constitutes the **Functional Architecture of the CAX System**. The Functional CAX Architecture described in 1 is derived from military operational needs and it is not constrained by any system topology or other CAX System Implementation considerations.

The **CAX System Topology**. This view defines and evaluates available options for providing the CAX functionality. As the first step in this process, six options are identified, each with a different degree of integration of CAX with CCIS and with a different degree of distribution of the CAX functionality itself. The second step is then to compare the CAX Architectural Options and come up with advantages and disadvantages of each of them. This analysis, provided in Section 2, is based on the Functional Architecture as well as on a set of assessment criteria such as User Satisfaction, Implementation/Operation & Maintenance Cost, Security, Technological Trends and Flexibility.

The **CAX System Physical Architecture** describes hardware and software components and their interrelationships for the CAX system. In future CCIS, as in other modern information systems, this physical architecture will not play the role it is playing today. New technologies available to implement functions on distributed systems and global data links will make it possible to concentrate on the functional and topological design of the systems. Even changes from one physical architecture to another regarding the distribution of functions in a network will be no major problem and will give the opportunity to decide on topological architectures as described in chapter 2 in accordance with the exercise requirements. Chapter 3 introduces the discussion on possible implementation options for the different topological CAX architectures.

Paper presented at the RTO SAS Lecture Series on "Simulation of and for Military Decision Making", held in Rome, Italy, 15-16 October 2001; Stockholm, Sweden, 18-19 October 2001; Virginia, USA, 23-25 October 2001; The Hague, The Netherlands, 10-11 December 2002, and published in RTO-EN-017.

2 CAX Functional Architecture

The (military) operational needs dictate that CAX and Decision Support Tools (DST) are integrated with the Command and Control Information System (CCIS). The Users should be able to use their CAX System from their location, through their operational CCIS. CAX and DST are considered as essential tools not only for training but also for Crisis Management. Although existing Simulation Models are focusing on training in the classical sense, the simulation technology has now been recognised as a powerful tool for:

(1) Situation Analysis;

(2) Sizing & Composition of Forces;

(3) Expanding the ability to respond to unexpected situations (Crisis Management);

(4) Exercising the operational CCIS for assessing system performance criteria such as functionality, flexibility, availability and reliability.

The full set of the operational needs, as perceived today, expands the traditional scope of a CAX Training System to include the following:

(1) Role Playing;

(2) Problem Solving;

(3) Case Studies (Role Playing);

(4) Analytical Simulation;

(5) War Gaming;

(6) Decision Support (What If).

The Training Subjects are required to cover:

(1) Military Operations;

(2) Rules of Engagement (Military, Political);

(3) Non-Military Missions (Crowd control, Civil population support, Environment protection);

(4) Time and Space Limitations (Planning Systems, Focus on Logistics, Mobility, Deployment, Evacuation);

(5) Crisis Management Functions (Political, Military Strategic, Military Tactical, Military procedural).

The Functional Architecture of a CAX and Decision Support System that could be implemented with existing Simulation Models but flexible enough and expansible to gradually cover all the training subjects listed above, is shown in the following diagram:

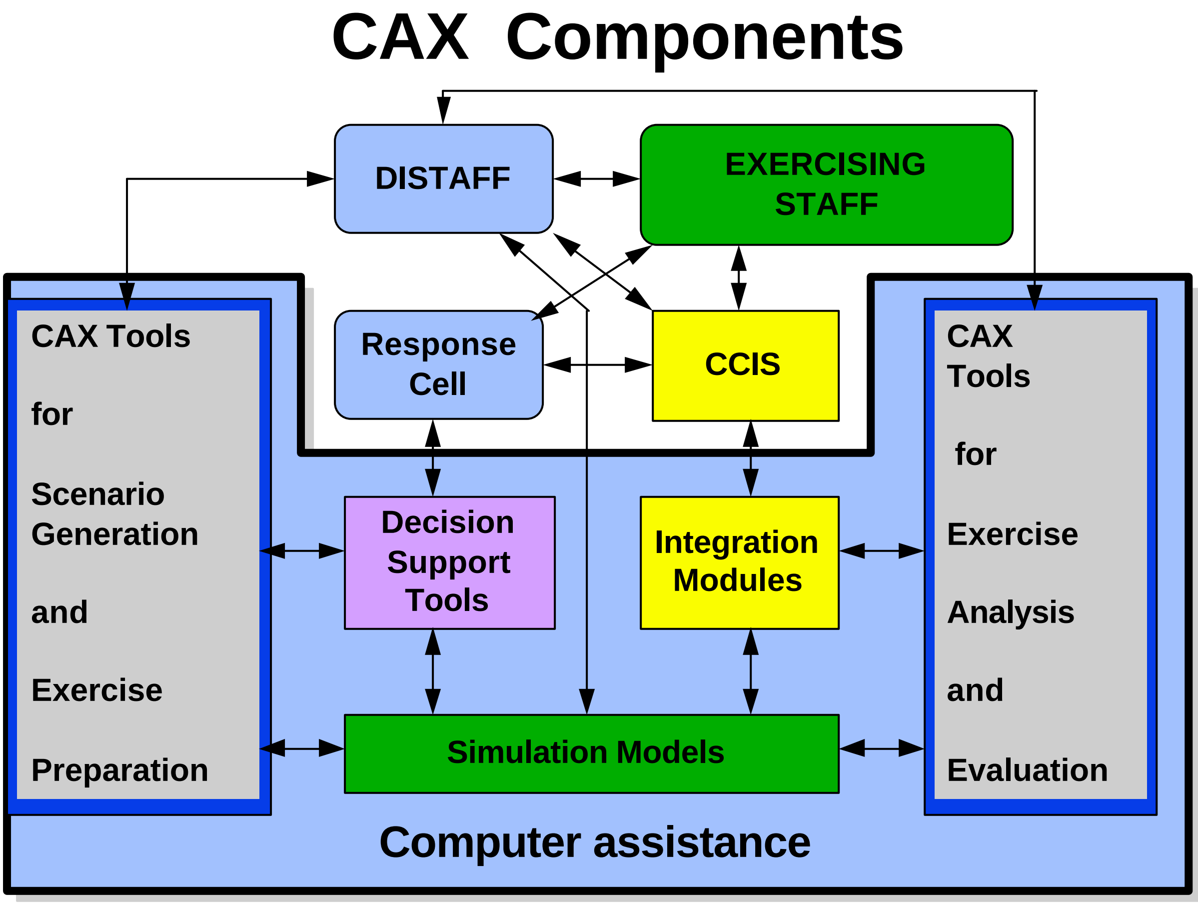

Figure 1: CAX Components

2.1 CAX Components

The Main CAX and DST Components are:

(1) Supporting Tools for Exercise Scenario Generation and for Exercise Preparation (Data Gathering etc.);

(2) Simulation Models for War Gaming;

(3) Integration Modules for:

- Integrating the Simulation Models with the CCIS
- Integrating the Simulation Models with the Supporting Tools
- Integrating the Simulation Models themselves;

(4) Decision Support Tools;

(5) Supporting Tools for Exercise Analysis and Evaluation.

Following is a short description of each component:

The Scenario Generation and Exercise Preparation Tools allow users to develop scenarios for different exercises, presenting those exercised with a variety of different situations. These scenarios can range from low to mid to high intensity. Scenarios can be developed for a specified period of time and can be edited as necessary. This tool will also allow controllers to produce documentation manuals. The scenario database of pre-selected CAX models should be accessible by the Exercise Controllers, who should have the capability to create, modify, and delete scenario elements. The Exercise Preparation Tools affect the exercise during the preparation phase. This function consists of entering start date data into the system. This will include force strengths, readiness factors, logistical status, and other data related to the friendly and enemy forces participating in the exercise.

The **Simulation Models** are the exercise drivers. They simulate combat operations as well as mobility and logistics. Future models are expected to cover the total spectrum of functions required by the Training Subjects.

The Integration Modules ensure the following interfaces:

(1) The interface between Simulation Models (This component is necessary to integrate different Simulation Models (e.g. Air and Land Models) in one Exercise. This is currently achieved though the High Level Architecture Protocol (HLA)).

(2) The interface between the Simulation Models and the CCIS

(3) The interface between the Simulation Models and the Decision Support Tools

The **Decision Support Tools,** as a CAX component, determine how the CAX capability can be used within the Command and Control Cycle (Maintain Status-Assess Situation- Plan- Decide- Execute) in support of the decision making process.

The **Exercise Analysis and Evaluation Tools** assist in gathering statistics and other information to conduct after-action-reviews at the conclusion of the exercise. A standard set of analytical tools should be available to evaluate the performance of those involved in the exercise.

3 CAX System Topology

3.1 Organizational Architecture Options

In order to support exercises in an automated manner, the military organisation, NATO or national forces, must decide:

(1) to which extent it wants to own, operate and maintain the capabilities that constitute an exercising environment i.e. to which extent it wants to be responsible for exercising environment components.

(2) where the various components of an exercising environment are physically located.

The first bullet above defines the level of integration of the CAX capability in the CCIS. The second bullet defines the level of distribution or concentration.

In this paragraph, various integration and distribution options are shown and their characteristics discussed. Underlying these options are 2 fundamental assumptions:

(1) exercising elements do not require exercise-specific tools because they use their operational CCIS;

(2) exercising headquarters staffs have the capability to exchange data over a digital network.

Six options will now be presented in which the organisational allocation of exercising environment components is varied. Four components are considered relevant for this discussion:

(1) the exercise preparation component is depicted by a diamond shape

(2) the exercise conduct component is depicted by a hexagon shape

(3) the exercise analysis and evaluation component is depicted by square shape

(4) the simulation component is depicted by a dotted ellipse;

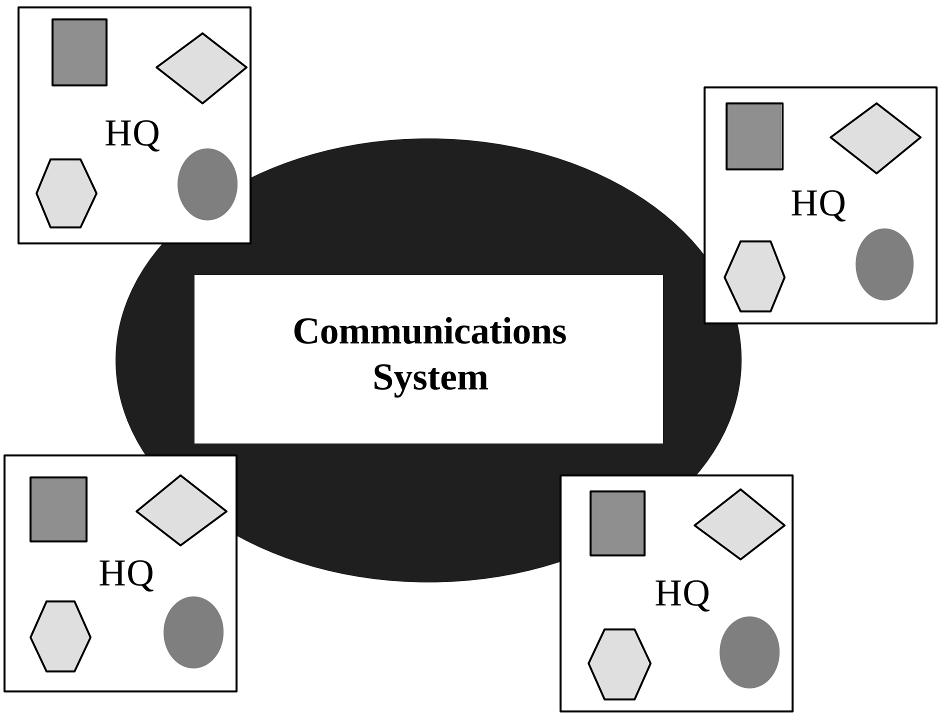

Figure 2: Fully Integrated CAX System Topology (Option 1)

The first option shown here describes a fully integrated architecture. The military organisation takes the responsibility to own, operate and maintain all exercise environment components. Furthermore, distribution is complete as each headquarters is provided with their own capabilities. The components may vary from headquarters to headquarters depending on the exercising requirements of each specific headquarters e.g. the emphasis on certain types of operations or on the level of detail may be different. Using these tools each headquarters can meet its own exercising needs and those of higher command echelons.

The second option shows a fully-integrated architecture. However the organisation has decided to specialise a headquarters in a certain function, in this case the simulation function. Reasons to do this may be that simulation environments require specific expertise, hardware and software to operate and maintain.

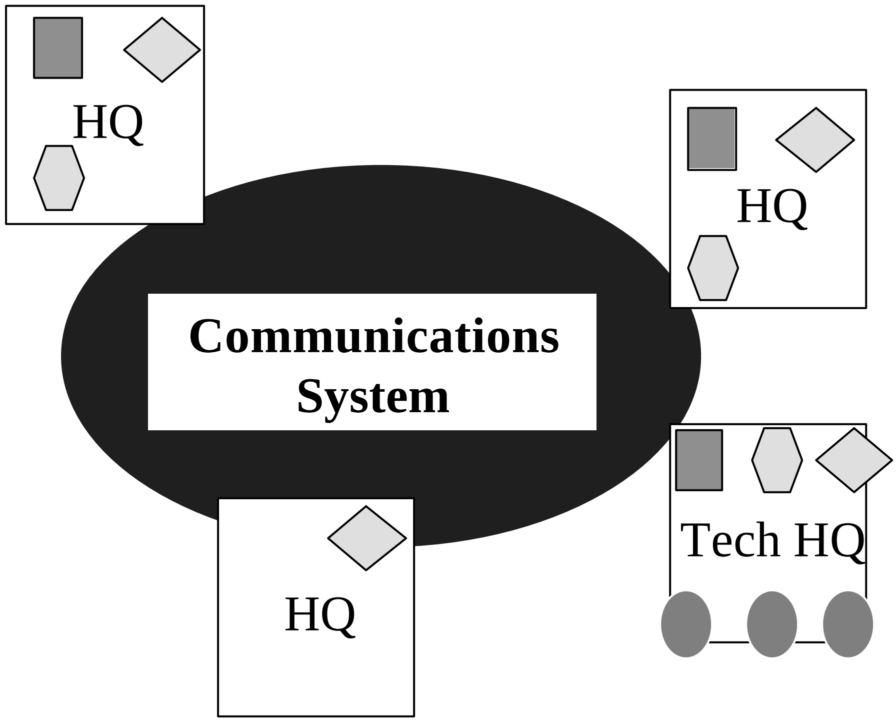

Figure 3: Fully Integrated Architecture with Technical HQ (Option 2)

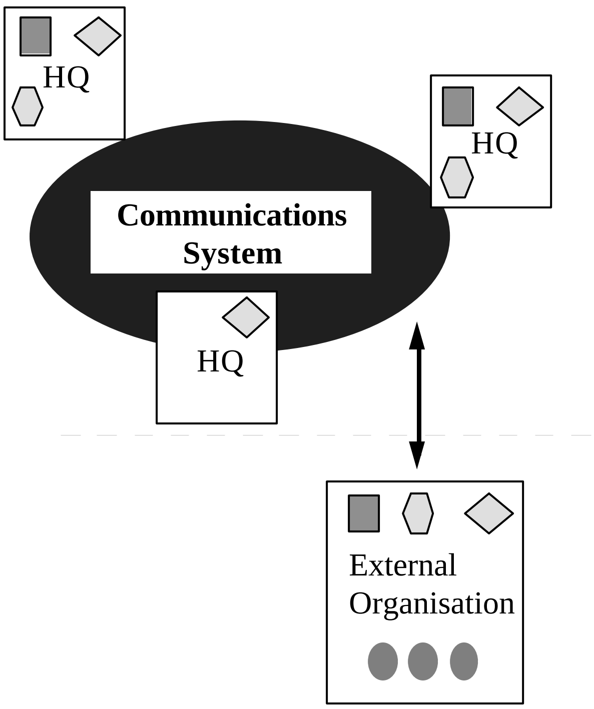

Figure 4: Integrated Architecture with External Organisation (Option 3)

A similar consideration as for option 2 may lead the organisation to leave the responsibility for certain functions with an external service organisation while retaining organisation-specific functions under its own control. This option is illustrated in option 3.

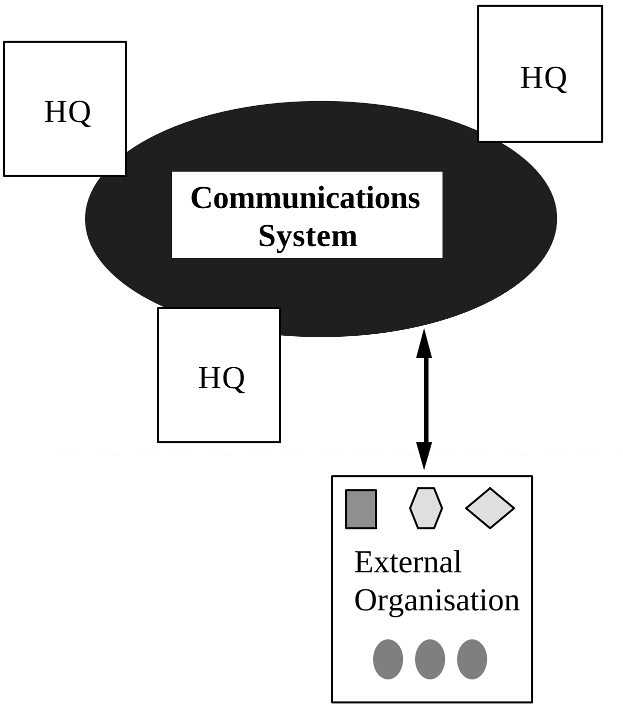

Figure 5: Non-integrated Option (Option 4)

For reasons of lack of specific expertise and capabilities, a non-integrated option can be selected as shown in option 4. The organisation uses tools and capabilities provided by an external service provider. For reasons of reduced management overhead or quality of expertise or unique service capabilities, a single service provider is selected. The exercising components are therefore concentrated within that service provider.

In order to increase the diversity of services, bring market competition factors into play, option 5 can be considered which varies from option 4 in the number and diversity of service providers. Within this option multiple cooperating and complementary service providers may support exercises. The service is therefore distributed.

Option 6 shows a variation on options 2 and 5. Indeed there is a need for exercise service providers to interface with the CCIS. The security implications of doing so are great. In a world of growing internetting and increasing anonymity of network users, military organisations may fear such an openness and security costs may become prohibitive. Therefore it may be interesting to integrate some functions in the organisation and specialise a headquarters in providing the buffer between the CCIS and the external service providers.

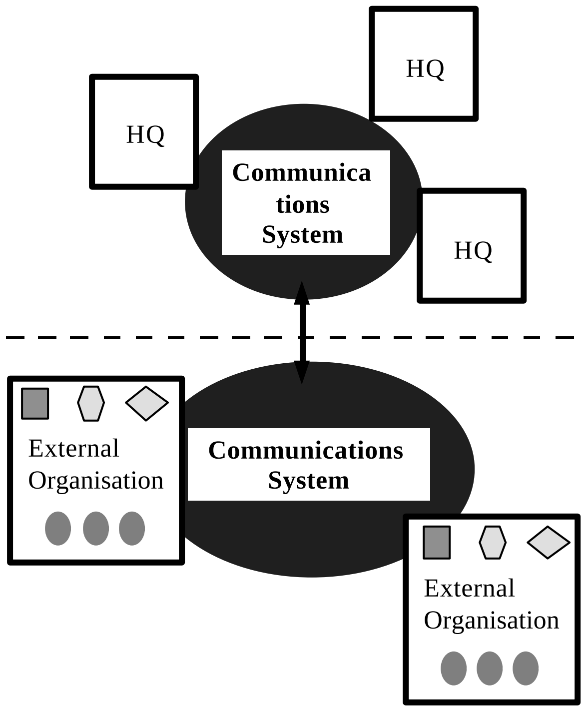

Figure 6: Distributed System with External Service Providers (Option 5)

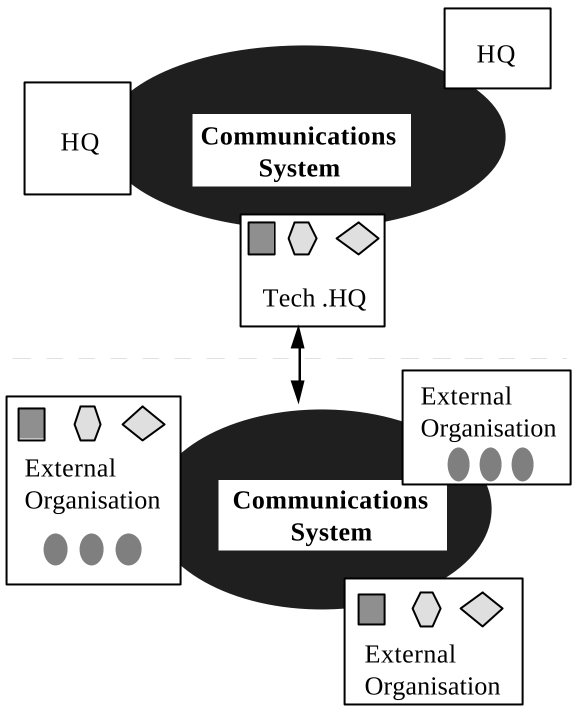

Figure 7: Distributed System with External Providers and Technical HQ (Option 6)

Obviously the permutations shown here are not exhaustive, however they are representative of potential future architectures and highlight the factors that are essential in generating and evaluating architectural options for an organisation, which wants to have the capability to exercise.

3.2 Assessment of the Organizational Architecture Options

The options described in the previous sub-section (3.1) were assessed on the basis of a set of criteria in order to derive some conclusions with respect to advantages and disadvantages of each option in comparison with the other options.

The criteria used for the assessment are the following:

(1) Satisfaction of all parties involved.

The parties involved are the Exercising Staff (trainees), the Control Staff (DISTAFF), the System responsible for the Operation and Maintenance and the System or Service Suppliers (Providers). This criterion covers the degree of support the involved parties can have in performing their role within the CAX activities. The criterion is sub-divided to cover:

(a) The parties involved in the exercise preparation;

(b) The parties involved in the Exercise Control;

(c) The Trainees;

(d) The parties involved in post-Exercise Analysis and

(e) The System "owner".

(2) Implementation Cost.

This criterion is self-explanatory.

(3) Cost and Effort for Operation and maintenance.

This is also self-explanatory.

(4) Security.

This is considered to be a critical factor for the adoption or rejection of an option for implementation.

(5) Openness to Suppliers.

The objective here is to be open to as many suppliers as possible in order to make maximum use the products available in the market.

(6) Operational Control of the CAX system.

The users prefer to have the maximum possible control over the systems they use. This is, to some extends an operational need, but also is related to the availability of the system to the user.

(7) Technological Trends.

This criterion examines to what extend the option follows the technological trends, as perceived today.

(8) Flexibility.

This criterion covers the degree to which the option facilitates the introduction of new applications, covering existing or new requirements, as the technology will offer more and more opportunities for this direction.

(9) Redundancy/Reliability.

This criterion covers all issues related to the availability of the system for the user, when needed, without interruption.

The table shown in the next page summarises the results of the assessment made by the expert group of the six CAX distribution options described in section 2.

The following conventions are used:

(+) indicates an advantage of the specific option under the specific criterion;

(++) indicates a strong advantage;

(-) indicates a disadvantage or weakness;

(--) indicates a major disadvantage or weakness;

(0) indicates a neutral situation (no advantage or disadvantage).

Table 1: Assessment of Alternative CAX Organisational Distributions (next page)

	Criteria	Integration	full	semi	semi	none	none	semi
		Service	none	none	partial	full; one	full; many	partial; many
1.								
	Preparation	+	++	+	+	+	+	
	Control	+	++	o	o	-	-	
	Trainees	o	o	o	o	o	o	
	Analysis	+	++	+	+	+	+	
	System ”owner”	--	-	o	++	+	+	
	Summary of 1	(o)	(++)	(o)	(+)	(o)	(o)	
2a)	Cost of Implementation	--	-	+	+	++	o	
2b)	Cost & Effort of Ops & Maint.	--	-	-	-	-	-	
3.	Security	+	++	o	-	--	o	
4.	Openness to Suppliers	-	-	o	++	+	+	
5.	Operational Control	+	++	o	-	-	o	
6.	Technological Trends	-	-	o	+	+	+	
7.	Flexibility to diff. Applic./Req ts.	-	-	o	+	++	+	
8.	Redundancy/Reliability	++	+	+	-	--	o	
	Total Summary	(-)	(++)	o	(++)	(+)	(+)	

The following general conclusions are derived from the above Table1:

(1) Option 1 is assessed to be the most expensive solution in both Implementation and Operation & Maintenance costs; This option is neutral in terms of the satisfaction provided to all parties involved, is very strong in redundancy/reliability, strong in terms of security and operational control and weak in terms of openness to suppliers. It is also less flexible and is not following the technological trends. Overall, this option is rated as weak with most of the disadvantages.

(2) Option 2 , compared with the other options, is the best for the satisfaction of all parties involved in CAX (mainly the users but also the system or service providers); It is also very strong in terms of security, redundancy/reliability and operational control. On the other hand, this option is rather expensive, less open to suppliers, not very flexible and not following the technological trends. Overall, this option is rated as very strong, especially in addressing the security problem as the most critical issue related to the CAX implementation.

(3) Option 3 is neutral with no major advantages or disadvantages.

(4) Option 4 provides a major advantage to the system Owner, is very open to Suppliers and also follows the Technological Trends and provides a high degree of flexibility for future applications. It is weak in redundancy/reliability.

(5) Option 5 involves the lowest Implementation Cost and provides the maximum Flexibility. Major weaknesses are in Security and Redundancy/Reliability.

(6) Option 6 , as a combination of Options 2 and 5, improves Security and Redundancy/Reliability, compared with Option 5 but involves higher Implementation Cost and lower degree of Flexibility.

4 CAX Physical Architecture

As described in the introduction of chapter 5, the CAX System Physical Architecture depends highly on available hardware and software solutions that will also be used for CCIS where the CAX system is to be integrated.

The assumptions for the topological architecture are that users of exercise environments will use their day-to-day working environment and that the HQs have the capability to exchange information amongst each other and with external organisations supplying CAX functions. These assumptions could be amended by the assumption that in every HQ and at the external organisations computational resources will be available to implement specific CAX functions.

Distributed Object systems and services will provide services that are beyond today's available client-server architectures. The server is now a function that could be also distributed on different computers on the network. This technology will allow solutions like the one described in ANNEX VIII but let it open to distribute the CAX system with its different functional parts on the network.

The different options for the topological architecture will not fix specific physical architectures because of the described assumptions.

5 SERVICES

The development of information technologies shows a general trend to move the system developer, integrator and end-user away from basic technologies to higher aggregated technologies, tools, and services.

The development of software is a good example for this change of view. Software development started with machine coding, came then to assembler programming, programming languages like FORTRAN and

COBOL, high order languages like ADA and C, development tools and environments. Now the object-oriented technology is an emerging paradigm for software development, which includes already dynamic distributed objects and services.

CAX designers/implementers will draw from a large stock of higher aggregated services offering a variety of products serving specified groups of basic tasks. These services will have been built on more basic technologies by others and will be commercial and governmental available. An example for such services is Geographic Information Systems (GIS).

The "art" of building CAX systems and CCIS systems will be to integrate these services into a system which fulfils the requirements. The requirements depend on training objectives that are derived from tasks (war tasks, crisis management, humanitarian aids).

A consequence of these developments is that basic technologies will play a decreasing role for the system designer/integrator; they may even not have to be known in detail.

Services available or to come are of increasing importance as building blocks for functionality and technical architecture of CAX systems and CCIS as opposed to the basic technologies.

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Automated Command and Control Information Systems (ACCIS) and CAX

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To be prepared for war is one of the most effectual means of preserving peace.

-George Washington

Abstract:

This paper provides an introduction to the relationship between an Automated Command and Control Information System (ACCIS) and Computer Assisted Exercises (CAX). After a brief historical review the paper gives an overview of existing definitions and descriptions of ACCIS and CAX. Based on a common sense understanding of the phenomena, the term "Operational Environment Simulation (OES)" is introduced. Common capabilities of ACCIS and OES are then identified as Common Services. It is concluded that both the ACCIS and the OES have much in common. It is recommended that future developments of ACCIS should follow the same standards and guidelines in order to maximize training benefit of CAXes and in order to minimize costs of development, operations and management of both systems. The NATO ACCIS architecture attempts to do exactly this.

Introduction

Since Field Marshal Montgomery developed NATO Command Post Exercise (CPX -1), which was held in April 1952 and attended by all of the top commanders in NATO and the national chiefs, five decades have passed. These five decades have seen an unprecedented technical revolution: the revolution of the information age. The information age is having a dramatic impact on all sectors of society: from the behavior patterns of the family to the phenomenon of globalization. The impact on military processes is in no way less dramatic: whereas in 1952, paper maps, grease pencil, mechanical calculators, lots of human brains formed the support core of military management or command and control, this core is becoming more and more computer based today. In 1952 command post exercises (CPX) were stimulated by response cells consisting of staffs mainly supported by the manual tools, similar to those used in the military management system. Developing computer tools to aid the decision process has been an endeavor almost right from the invention of the computer at the end of WWII. And indeed military requirements and funds were the driving force for the creation of such tools. First pushed by the need to find the enemies' crypto graphical methods and keys, the computer was created. The revolution of the information age however took off with the invention and affordability of the microprocessor in the 70ties, the Internet[1] in the 80ties and the world wide web (WWW)

[1]) Das Internet ist die am schnellsten wachsende Struktur, die je vom Menschen geschaffen wurde. *(Zitat: Prof. Rudolf Beyer, Institut für Informatik der TU München)*. Approximate Translation: "The Internet is the fastest growing structure ever created by the humanity".

Paper presented at the RTO SAS Lecture Series on "Simulation of and for Military Decision Making", held in Rome, Italy, 15-16 October 2001; Stockholm, Sweden, 18-19 October 2001; Virginia, USA, 23-25 October 2001; The Hague, The Netherlands, 10-11 December 2002, and published in RTO-EN-017.

in the 90ties. We can attribute the first two phenomena to military funds whereas the WWW came from scientific world. Today's developments in information and communications technology (ICT) are largely driven by industry and commerce.

The technology of Command Post Exercises, like any civil and military sector, has been taking part in this revolution. The traditional Kriegsspiel[2] has been giving way to computer supported simulations. NATO for the first time conducted a Computer Assisted Exercise (CAX) in 1989, called ACE '89. Response cells (RC) were equipped with a set of simulation models, simulating air, ground and naval engagements. Exercise controllers and response cells were equipped with their own command and control information system. The concept of the Operational Environment Simulator (OES), entailing computer based models **and** automated CCIS both to assist exercise support staff was born shortly thereafter[3].

Already in the 80ties first ideas were published on interfacing the then emerging automated command and control information systems (ACCIS) with the simulators. In order to be effective and efficient, the implementation of these interfaces for the purpose of computer assisted exercises (CAX) however had to wait for the information and communications technology (ICT) of the 90ties. The implementation is ongoing….

The Problem

Computer Assisted Exercises (CAX) are conducted usually in order to reach one or both of the following objectives:

- to exercise and train staff in the accomplishment of their missions and tasks,
- to test and verify organizations, procedures and tools of command and control systems.

Both objectives require the staffs which are being **exercised or trained** or which **operate and use tools for test and verification** purposes to be exercised using the tools which they would use in support a command and control problem in the real world. A command and control problem whether for real or for CAX could address a peace support mission, military crisis management or conflict resolution, it could deal with a strategic problem, an operational problem or a tactical problem. It could deal with a single staff function, with an entire functional area (FA), a complete headquarters, or a multi-echelon command structure. There are types of CAX, which support any combination of the above, just as there are many operational environments in the real world.

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[2]) See www.aimonline.com/history.htm: "Wargaming has a long history and has throughout the ages, changed history's path, either directly or indirectly. Wargaming has had more of an effect on the course of human events than is realized by most people. It all started around 3000 B.C., in China, with a man named Sun Tzu. A general and the earliest known philosopher on the subject of warfare, Sun Tzu also created the first known war game." …."The major breakthrough in wargaming didn't come until 1811 in Prussia. In that year, Baron Von Reisswitz, a civilian war counselor in the Prussian court in Breslau, invented a game called **Kriegsspiel** (The War Game). Baron Von Reisswitz introduced the game to the Prussian princes Wilhelm and Friedrich and they were so impressed by it, that it was adopted by the Prussian military to practice on-the-field command decisions. The game was played on a sand covered table and used wooden playing pieces to represent the different types of units. The rules covered movement and the effects of terrain. Combat was resolved using an odds table. Lieutenant George Heinrich Rudolph Johann Von Reisswitz, from the Prussian Guard Artillery and son of Baron Reisswitz, modified his father's game and made several improvements. He replaced the sand on the table with colored squares to indicate different terrain types. The young Lieutenant also modified the rules to include battalions of infantry and fusiliers, squadrons of cavalry and dragoons and because of his own military experience, rules were added to include the use of field artillery and siege guns. **Kriegsspiel** was played by Prussian military officers to prepare for battles and was given credit by Prince Wilhelm as helping in the Prussian victories of 1870. Such an influential and popular game, couldn't be contained for long and **Kriegsspiel** found its way to Italy, Russia, Japan and in 1867 the United States. …."

[3]) Schmidt, W.H.P.: Computer-Assisted Exercises (CAX), A Technological Challenge To Nato; STC-PP-305, Aug-92; presented at AFCEA Brussels October 1991.

Just as the tools in support of staff functions and residing on the ACCIS need to interoperate with the real world for solving real world problems, they need to interface with the simulated virtual world of a CAX. We call this virtual world the OES, the Operational Environment Simulator. There needs to be a conceptual SWITCH, which hooks the ACCIS either to the real world or to the virtual world. In doing so, there are obviously a number of INTEROPERABILITY requirements to be met. There are DATABASES involved, which need congruency of contents. There are APPLICATIONS and Computer Human Interfaces (CHI) Interfaces involved, which should be identical in order to reap the full training benefits.

Finally there is the philosophical question of concept: "Is the OES not part of ACCIS anyway?"

This lecture deals with these problems: the switch, interoperability and databases, applications and CHI as they are related to the OES and the ACCIS.

Before we get into the details of these topics we need to cover some definitions.

Definitions

ACCIS, the Automated Command and Control Information System

The glossary of terms attached to the **NATO C3 TECHNICAL ARCHITECTURE**[4] defines the "**automated command and control information system (ACCIS)" as "**A NATO programme to provide command and control information systems to support NATO military commanders". The same document provides the following Note: *"Use of this term" namely ACCIS " as a generic term meaning a command and control information system that has been automated is to be avoided. See also:* ***command and control information system***." Looking at "**command and control information system (C2IS, CCIS)" we find:** "An information system which provides military authorities with support for command and control purposes" with the following "Notes:

- *Command and control information system is complementary to command and control communication system.*

- *The term "command, control and information system (CCIS)" is recognized in certain older NATO documents to mean "an integrated system comprised of doctrine, procedures, organizational structure, personnel, equipment, facilities and communications which provide authorities at all levels with timely and adequate data to plan, direct and control their activities." Use of this term is to be avoided as well as the use of the abbreviation CCIS in that sense. " And it goes on with: "See also:* ***consultation, command and control****, and,* ***management information system***"

At this point it becomes useful to stop looking for definitions and instead to use an intuitive approach to ACCIS for the purpose of this lecture. The above considerations are nonetheless valuable as it opens the door to NATO's thinking on these topics.

The intuitive approach to ACCIS results in the following loose description: An ACCIS is a collection of computer supported tools which assist commanders and their staff in executing their command, control, consultation and management tasks. These tasks can be looked at from an information processing point of view as related to the command and control cycle (e.g. situation monitoring and assessment, planning courses of action, decision making, decision execution). They can also be looked at from a viewpoint of mission (consultation, management, command and control) and supporting military functions, such as Intelligence, Operations, and Logistics.

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[4]) VOLUME II - ARCHITECTURAL DESCRIPTIONS AND MODELS (Version 2.0 [Dec 15, 2000] - ISSC NATO Open Systems Working Group)

CAX, Computer Assisted (or Aided) Exercise(s)

Unfortunately, the Glossary used so successfully above does not contain a definition of CAX. The Allied Command Europe (ACE) *CAX Planners Course* 1999[5] however provides a useful definition: A CAX is *"A Command Post Exercise (CPX) in which computer-based simulation models are used to place commanders, staffs and their command and control systems in an operationally realistic environment in order to perform decision-making, practice staff procedures and co-ordinate between headquarters."* The term "CPX" in turn is defined in the US DOD and the NATO Glossary of Terms as *"An exercise in which the forces are simulated, involving the commander, his staff, and communications within and between headquarters."* The conduct of a CAX therefore, by definition, requires a **computer based** Operational Environment Simulator (OES), including the simulated forces as a prime aspect.

After this common sense definition we shall not refrain from exhibiting some more descriptions[6].

- From **SHAPE**: An exercise in which the control-group conducting and controlling the exercise utilize computers and other advanced technology devices to simulate an operational environment to the commanders and staffs, who are the players or the primary training activity of the exercise.

- From **SACLANT**: CAX involves the specific use of computers in simulation of a range of joint military operations for both live and synthetic exercises and day-to-day training. CAX will provide the most beneficial contribution in synthetic exercises, particularly dynamic gaming which explores joint force capability and tactics in the new situations likely to be faced by NATO Forces in the future. Ultimately, NATO-wide CAX should be developed that employs a network of NATO and national computer systems to represent crisis situations in which force capabilities can be assessed and realistic training can be conducted.

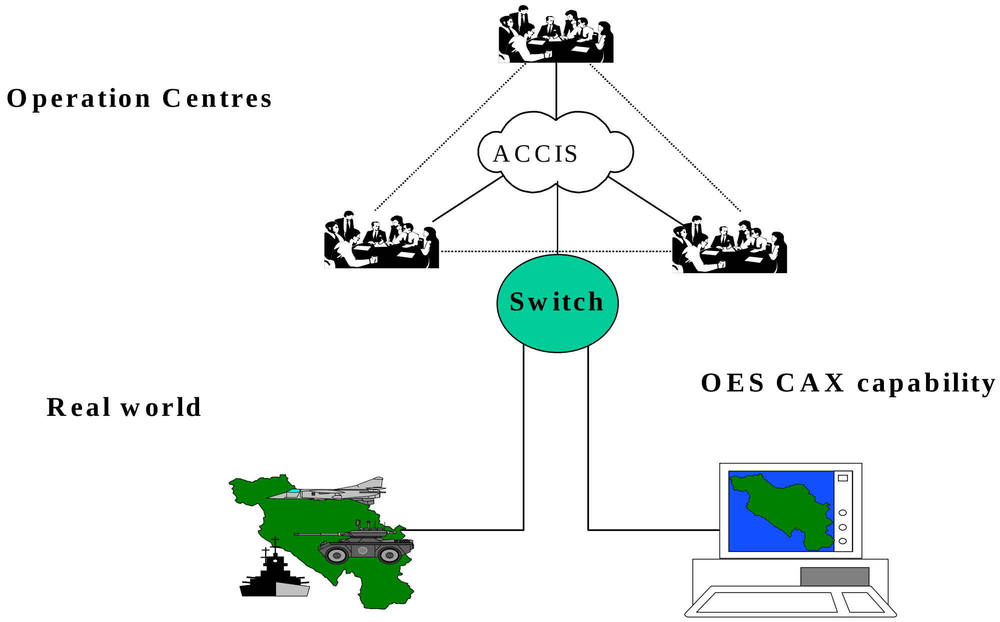
- **WARRIOR PREPARATION CENTER (WPC):** An exercise using computer models designed to place the command and control elements of headquarters in a realistic, stressful combat-like environment to stimulate decision making, command and control staff interaction and coordination at the operational-level of war.

Whereas these descriptions are fairly close to the common sense description above, LTSS 40 contains additional descriptions, which take a more general approach. For the purpose of clarity these descriptions are not being used here.

[5]) Unpublished presentation by NATO C3 Agency, The Hague, the Netherlands.
[6]) all from: NATO, AC/243(LTSS)TR/40, Final Report, COMPUTER ASSISTED EXERCISE TECHNOLOGY, DEFENCE RESEARCH GROUP,AC/243(LTSS), 15 Feb 1995.

Conceptual Architecture - The Switch

As shown below the ACCIS needs to operate in two modes: the Operational Mode (OM) and the Exercise Mode (EM).



Operational Mode (OM) and Exercise Mode (EM)

There needs to be a conceptual switch which performs certain actions inside the ACCIS and outside the ACCIS in order to interface the ACCIS to either the real world or the OES. In switching from OM to EM, inside the ACCIS the operational databases need to be deactivated. Instead of those the exercise databases come into play. Outside the ACCIS, the communications interfaces to the real world will be disconnected and instead those of the OES will be switched in. In reality however an ACCIS can never be completely in EM as certain vital real world watch functions must be operational 24 hours a day, 7 days a week. Hence in designing the ACCIS careful consideration must be given about the deactivation/ activation processes.

We shall first discuss the communications interfaces, then the data base aspects.

Communications Interfaces

In the OM the ACCIS communicates to its real world environment via its doctrinal communications systems. These systems carry a number of communications channels connecting it to other ACCIS elements belonging to this real world environment, namely ACCIS of the subordinate units, lateral units, higher echelons, governmental and non-governmental organizations, etc.. In a CAX only those doctrinal communications, which are subject of being exercised, are left in place as part of the ACCIS. All other communications elements in a CAX are represented by the OES. At certain points the doctrinal communications systems require to be interfaced with those of the OES. The OES therefore needs to have communications interfaces, which match those of the ACCIS. Whereas it seems to be a simple matter to switch the actual communication links from real world to OES, the doctrinal systems are complex and it is by no means trivial to make sure that the logical channels match.

Some typical communications capabilities in use are:

- The formal messaging systems, with their prescribed formats and transfer requirements, governed by protocols such as AdatP-3[7] for content and the MMHS protocol[8] for transfer purposes.

- The military Intranets, following closely the evolution of the standards governing the public Internet and commercial Intranets.

- Specialized point-to-point systems or circuit switched systems for highly responsive traffic (e.g. video conferencing).

The OES requires modules, which can match those capabilities of the ACCIS[9] in order to provide the primary training staff with experience to the utmost degree possible. If the training staff in the real world do their job for example by pulling information from the military Intranet then the OES needs to feed this Intranet with the required information. If the training staff gets information through the messaging mechanisms of the ACCIS those need to be supported by the OES as well.

The switch needs to make sure that the proper systems and protocols are activated in the ACCIS and the OES in time for the CAX to happen.

Databases

Types

In a military operation there are four types of data involved in the simulation environment:

- **Dynamic military unit data**, which contain information about type of unit, its strength, combat effectiveness, equipment, location, subordination ("order of battle"), posture, etc. The term unit means to cover all types including e.g. engineers, intelligence collectors, communication units, transportation, and headquarters. Those data change in the course of a campaign.

- **Static reference data**, which contain information about weapon characteristics, means of transportation, characteristics of sensors and electronic warfare emitters, personalities, etc. Those data by definition do not change during a campaign.

- **Geographic data,** which contain information about the terrain and geopolitics, such as national borders.

- **Weather data**, which are self-explanatory.

Dynamic Military Unit Data

Let me turn to the **dynamic military unit data** first. The ACCISs of nowadays and for some time to come have not achieved one single integrated database. Instead users, jointly with developers, have designed and implemented subsystems, which cover partial aspects of the total operation. In NATO those partial aspects are called "Functional Area Systems" or FASs. Whereas this situation is not ideal it has been the only way to make progress. The alternative would have been waiting for the coordinators to propose and agree

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[7]) STANAG 5500:1987, NATO MESSAGE TEXT FORMATTING SYSTEM (FORMETS), Allied Data Publication 3 (ADatP-3).

[8]) MMHS PROFILES – e.g. AMH1x(MA) - Military Message Handling System (MMHS) - Common Messaging

[9]) For a more complete description of NATO's protocols see: http://194.7.79.15/ VOLUME 2 [ARCHITECTURAL DESCRIPTIONS AND MODELS] / PART 3. NC3TA REFERENCE MODELS

uniform approaches and definitions. Whereas this is tedious and loaded with many problems in a pure national environment, in NATO's 19 Nations it is and will remain a dream for some time to come.

Taken this as a given, the databases of the OES and the ACCIS nevertheless need to have congruency at least in content. In the preparation phase of an exercise the exercise databases of the ACCIS and the OES need to be initialized, in order to reflect the start situation of the exercise. Normally the exercise planner assisted by staff specialists from the functional areas would accomplish this. They would take a copy of the ACCIS database (we use the term database to mean the collection of all FAS databases, relevant to the exercise) declare this copy as the initial working copy of **the exercise database** and modify the data elements to fit the exercise scenario and the exercise objective. Once this work is completed, a transformation process takes these ACCIS exercise data and converts them into a form suitable to fit into the OES (the simulation database). Then the database of the OES is initialized. The transformation process usually involves structural conversions in order to make the data formats compatible with the simulation algorithms. Furthermore aggregation and/or de-aggregation may be required for the same reason.

Transformation/initialization are tedious processes, as in the normal case the OES and the ACCIS have been developed under different rules and standards. These processes are highly dependent on human input. In order to minimize errors which are easily introduced a verification process supported by an exercise visualization system is necessary. The end result of this work is that both, the ACCIS and the OES at exercise start have databases identical in contents, as far as the simulation impacts on the data re concerned. After start of the CAX the data of the OES are changed by the simulation and in turn changed in the ACCIS through the software and human elements, which implement the communication protocols, discussed above (see communications interfaces).

Static Reference Data

Static Reference Data contain information about weapon characteristics, means of transportation, characteristics of sensors and electronic warfare emitters, personalities, etc. Static reference data are exchanged once, before the start of the exercise. During execution these data remain unchanged. The process of initialization is identical to that for dynamic data however may not be necessary for each exercise as a repository will be increasingly available after each exercise.

Geographic Data

Geographic data require a special consideration for two reasons. Firstly, CPXs (which include CAXs) may operate in artificial terrain and geopolitical settings (in short geodata). The OM in ACCIS always operates on real world geographic and geopolitical data. Secondly the OES may employ a simulation model, which uses a representation of the real world, which may not be found in the ACCIS (if ACCIS operates simulation based decision support tools, they may well be found!). The ACCIS usually employs some form of a Geographic Information System (GIS). Military GIS usually obtains the geodata in formats supported by the national geographic institutions. There are three processes involved:

- Generating the Digital Geographic Products:
    - By National Survey Agencies and governed NATO Geo Policy

- Configuration of Operational GIS Database within HQs
    - By Chief Geo Officers and Regional Geo Policy

- Utilization of Geo Applications and Database in Operational ACCIS
    - Military Users and ACCIS Staff in Accordance with operational plans
    - Digital Atlas on Staff Officers' Desktop

The resulting digital geodata products are usually made available in the following formats: DCW[10], VMAP[11], ADRG[12], DTED[13]…. These formats may not be compatible with the algorithms used in the OES.

Hence there is the additional requirement of the GIS for format conversion: During the exercise initialization process the geodata bases in the ACCIS and in the OES require to be made identical in contents. The conversion process should be possible in both directions, as it is necessary to generate OES geodata from real world products and as it is necessary to generate ACCIS geodata in ACCIS format from products which have been generated on the OES as an artificial world. Geoproduct converters are available for a variety of formats.

Weather Data

Weather data in ACCIS are usually obtained from military and civil weather stations, including Internet supported facilities. In ACCIS these data are largely used for human interpretation, correlation and assessment. There are special ACCIS weather services, which deliver data, which can be processed automatically, such as for flight planning, artillery purposes.

In OES weather data are influencing calculated simulation results often without human intervention. Data structures containing weather data of the OES are therefore normally part of the simulation model. Their representation may therefore be totally incompatible that in the ACCIS.

Therefore software-based processes are required which are similar to those affecting dynamic military unit data (see above).

The Computer-Human Interface (CHI[14])

In any ACCIS or OES excellent familiarity with the CHI is part of the staffs' personal profile. Efficiency of staff work is vitally dependent on this capability. Hence one single CHI for OES and ACCIS must be the objective.

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[10]) The Digital Chart of the World (DCW) is an Environmental Systems Research Institute, Inc. (ESRI) product originally developed for the US Defense Mapping Agency (DMA) using DMA data.

[11]) See http://164.214.2.59/publications/vmap0.html: Vector Map (VMap) Level 0 is an updated and improved version of the National Imagery and Mapping Agency's (NIMA) Digital Chart of the World (DCW®). The VMap Level 0 database provides worldwide coverage of vector-based geospatial data which can be viewed at 1:1,000,000 scale. It consists of geographic, attribute, and textual data stored on compact disc read-only memory (CD-ROM). The primary source for the database is the 1:1,000,000 scale Operational Navigation Chart (ONC) series co-produced by the military mapping authorities of Australia, Canada, United Kingdom, and the United States. The complete database is available on a set of four CD-ROM's and contains more than 1,800 megabytes of vector data organized into 10 thematic layers. VMap Level 0 includes major road and rail networks, hydrologic drainage systems, utility networks (cross-country pipelines and communication lines), major airports, elevation contours, coastlines, international boundaries and populated places. VMap Level 0 includes an index of geographic names to aid in locating areas of interest. VMap Level 0 is accessible directly from the CD-ROM or can be transferred to a hard drive and used in many geographic information system (GIS) applications.

[12]) ARC Digitized Raster Graphics (ADRG): ARC (equal Arc second Raster Chart/map) Digitized Raster Graphics (ADRG) are digital raster representations of paper graphic products. Maps/charts are converted into digital data by raster scanning and transforming the map image into the ARC System frame of reference. Data collected from a single chart/map series and scale will be maintained as a worldwide seamless data base of raster graphic data with each pixel having a distinct geographic location.

[13]) see http://164.214.2.59/publications/specs/printed/DTED/DTED_1-2.html: PERFORMANCE SPECIFICATION:DIGITAL TERRAIN ELEVATION DATA (DTED);METRIC MIL-PRF-89020A,19 April 1996, SUPERSEDING MIL-D-89020, 28 May 1993

[14]) The term CHI is preferred over the term human computer interface (HCI), as it associates the analogy to the 'chi' in humans. See e.g. Angel Thompson: Feng Shui, ISBN 0-312-14333-8, 1996, pp 169-171.

Unfortunately both the ACCIS and the OES have been developed from different backgrounds (one from the world of command and control, the other from the world of operational research). In cases where differences do exist the training audience must not be exposed to the man-machine interfaces of the OES: The staff would be incorrectly trained and unlearning would need to take place.

Identicality of the CHI would deliver additional exercise benefits, as those staff, which operates the OES, would be ‘exercised on the ACCIS’ as well.

For the reasons above, any new development should follow the same CHI standards.

Fortunately much of this is becoming reality by default as the commercial and home based computer tools are converging and building blocks from theses environments are the most effective ones to use in the both the ACCIS and the OES. Office automation is an obvious example of this happening: the PC tools offered by Microsoft have a worldwide market share of over 90% [15] of the Operating System and Office Automation Market. Whereas this is most welcome from the viewpoints of training efficiency, we may not like it for other reasons[16].

ICT Services in ACCIS and OES

We have tried to show that there is not really much difference between the ICT (Information and Communication Technology) functionality required in the ACCIS and those required in the OES. The difference, if any at all, is in the emphasis: the ACCIS world has been created from the world of information management, communication and presentation; the OES world has been created from the world of Kriegsspiel, war gaming and simulation. Simulation models are nowadays being included in ACCIS, in order to answer the “what if questions” coming up during the planning and decision phase of the command and control cycle. Information management, communication and presentation tools are being included in the OES as part of the command and control support required by response cells, directing staffs, exercise analysts, etc..

The evolution of ICT, since a considerable number of years, shows a general trend of moving the system developer, integrator and end-user away from basic technologies to higher aggregated technologies, tools, and services.

OES designers/implementers draw from a large stock of higher aggregated services offering a variety of products serving specified groups of basic tasks. These services will have been built on more basic technologies by others and will be commercially and governmentally available. Examples for such services are Geographic Information Systems (GIS).

The "art" of building OES systems and ACCIS systems is to integrate these services into a system, which fulfils the exercise requirements. The requirements depend on training objectives that are derived from the mission (e.g. peace support, crisis management, conflict resolution).

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[15]) http://ig.cs.tu-berlin.de/w2000/ir1/t06-01/: Technische Universität Berlin Informatik und Gesellschaft, Information Rules Wintersemester 2000, Vorlesung "Markt und Wettbewerb 3"

[16] *) http://www.zeit.de/1999/46/199946_microsoft_gates.html:"*Wohl selten hat jemand die verwirrenden Mechanismen der Softwareindustrie so klar und durchschaubar dargelegt wie Jackson in seinem sogenannten *findings of fact." (DIE ZEIT, 11. Nov. 1999).* Approximate tramslation:Rarely has anybody explained so clearly the confusing mechanisms of the software industry as judgeJackson in his *findings of fact.*

The following services are playing a major role in the design and implementation of OES and ACCIS systems. They are described in the remainder of this chapter summarizing the findings of LTSS 40 and adapting them to the status of today's ICT.

1. **Messaging and Collaboration**

Industry provides solutions for collaborative work that bridges people and knowledge, and maximizes investments in existing technology. Modular and standards-based software that easily integrates with different applications and operating platforms are available. These enable organizations of all sizes to communicate, collaborate, share knowledge and conduct operations both internally and via the Internet.

Network services put together different technologies in the communications area in order to achieve packages of integrated services. Web technology with its commercial-off-the-shelf (COTS) servers, search engines, indexing schemes, browsers, value added applications services and data provision have come a long way since the publication of LTSS 40. But the basic services seen by the LTSS at that time address and embrace them. Use of open standards and well-defined and supported protocols must be mandatory. By adhering to this principle the system developer will be able to select from a gigantic market place the best packages. These include[17]:

- Directory service
- Message Handling
- E-mail
- Wide Area Information Browsing Services ("portals"; WAP[18])

2. Communications Systems Planning Services

Communications Systems Planning Services will provide tools to plan the communications for CAX, i.e. the communications inside the OES and its interfaces to the doctrinal communications system of the ACCIS.. They will take into account commercial, governmental, and military services available to support an actual CAX in a specific geographical area.

3. **Security Services/Packages**

Security Services/Packages will bundle different technologies to build the necessary security boundaries between an ACCIS in EM and the OES. These services will be available as separate packages that could be used on commercial systems and by network providers. These services range from crypto services to firewalls.

4. **Object-oriented component based technology**

The object-oriented technology will allow sharing software written for different applications. This opens the way for using libraries that could be commercial, governmental or even open and public. 20 years after the launch of the PC, software "development" turns into "software production". For example using ActiveX/COM (component object model)-interfaces, software components can communicate with each other; hence the capabilities of highly sophisticated and well-tested components can be easily integrated and exploited. Different

[17]) see e.g. Microsoft Exchange, LOTUS Domino

[18]) Wireless Application Protocol

high-level applications will thus be built upon the same basic components – finally. Such components can be:

- Applications
- User interfaces
- Data
- Objects

5. Archiving and Retrieval Technology (A&RT)[19]

A number of commercial A&RT products are available and in use on some NATO ACCIS FASs.

A&RT search and categorization technology is available which provides a robust, fault-tolerant and 'infinitely' scalable approach to information retrieval -regardless of whether you are deploying a FAS portal or OES database site. Powerful indexing, which can bring together content from all ACCIS and OES information sources is available. NATO C2 and CAX rules and categorization techniques are to be applied consistently across all information. Whether information is contained in a workflow management repository, a Microsoft Word file on a server across the street, or an HTML file on a Web server across the country, A&RT can index and search it. Supported formats include PDF[20], XML[21], all popular business applications and structured data such as that found in ODBC[22] databases.

By brokering queries to the servers that are best able to handle them, (A&RT) can deliver the most robust, high-performance search and categorization capabilities available.

This means that no longer for each kind of information, like map or terrain data, or mass data like fittings and equipment an own service needs to be implemented and integrated with the others.

The functions supported by such a service include:

- Indexing
- Search
- Filtering
- Interpretation
- Correlation
- Presentation

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[19]) Capability description taken from Verity K2

[20])PDF= Portable Document Format (PDF) is the open de-facto standard for the distribution of electronic documents world wide.

[21])XML= The Extensible Markup Language (XML) is the universal format for structured documents and data on the Web. See also www.nc3a.nato.int/symposia/xmlworkshop/home.html for "The NATO C3 Agency XML Workshop", Nov 1999.

[22]) http://www.microsoft.com/data/odbc/default.htm : Open Database Connectivity (ODBC) is a widely accepted application programming interface (API) for database access. It is based on the Call-Level Interface (CLI) specifications from X/Open and ISO/IEC for database APIs and uses Structured Query Language (SQL) as its database access language.

6. **Multimedia Services**

Multimedia systems will integrate different technologies to support the design of user interfaces giving new functionality regarding the interaction between users and between the user and the system (CHI) as well as capturing actions of users and system states. It includes:

- Video teleconferencing
- Sound
- Recognition of
  - Voice and Translation
  - Individuals (facial characteristics and expressions; body movement and gestures)
  - 3D-Pointing (Hand movements near or on large screen displays)
  - Freehand drawings, incl. handwriting
- Hyper information
- Radio/Television
- Remote Collaborative Work

The use of these services in OES and ACCIS systems is commensurate with the spread of multimedia systems in the commercial environment and the homes, today and tomorrow.

7 **Rapid Prototyping, Simulation Demonstration Environments**[23]

Basic technologies like the object-oriented technology and user interface technologies will support rapid prototyping and the generation of demonstration environments. To a far broader extend than today other services e.g. libraries as explained in item 4 above will be used. This service is very helpful for a user driven development of systems, both OES and ACCIS.

8 **Office Automation Environment**

Office automation packages include standard software packages like spreadsheets, word processing, desktop publishing, presentation, project planning etc. These packages are available on every hardware/software platform. The use of a common environment will streamline tasks and would improve the cost-effectiveness of OES and ACCIS. See also CHI above.

9 **Workflow Management Systems**

The next step after office automation in the sense of working in an integrated environment handling the different entities (including multimedia documents) in an office is the preparation, editing, distribution, updating of these entities and the organization and the support of collaborative work. Workflow Management systems will provide this service. The effective implementation of such a service requires careful systems analysis and discipline. If not done properly we can see organizational pitfalls. Effective commercial systems are available in abundance.

11 Automated Explanatory Briefings Associate

The Automated Explanatory Briefings Associate is based on techniques to access and present data at varying levels of abstraction based on models of users and tasks. It uses multimedia co-ordination of speech, text, and graphics.

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[23])see e.g. www.dsdm.org

12 Geographical Information Systems

Geographical Information Systems (GIS) as a service in the future will be more than today's systems. They will include not only terrain and map data, representation, and display, but also information regarding political, economical, ecological, environmental, ethical, racial, and religious structures. The systems will include tools to retrieve, evaluate, analyze, and update the information provided. Gazetteer services are becoming richly available.

Conclusion and Recommendation

From the considerations in this paper it has become obvious that OES and ACCIS have many software commonalities covering the entire spectrum of communications interfaces and protocols, data bases, basic ICT services, applications support and CHI. In order to reap the full benefits for the user, in terms of readiness and efficiency it is mandatory that both systems are governed by the same standards. In order to produce cost-effective systems it is mandatory that the same tools are used in both systems. NATO has recognized these requirements: the OES has become a module of the ACCIS, at least in concept. The NATO C3 Architecture[24] is recommending the use of n-tier architecture of software. Clearly this recommendation stems from the technological trends of the next software generation. This software will have at least three tiers: A lean client, a number of applications servers and a number of client/server databases. OES and ACCIS applications will run on this architecture using and sharing the same components. It is highly recommended that the Nations take the same attitude.

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Disclaimer

The conclusions and opinions expressed in this document are those of the author cultivated in the freedom of expression which is found in the fresh air and clear water of the Austrian alps. They do not reflect the official position of NATO, for which the author was working until 2000, nor do they reflect the position of the authorities of Germany, of which the author is a national, nor of the authorities of Austria, which is providing the author's "operational environment".

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[24]) http://194.7.79.15/

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Practical Examples and Future Needs for Computer Assisted Exercises at the Operational Level of Military Decision Making

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Summary

Computer assisted exercises have developed over the last ten years into the most cost-effective method to perform collective headquarters training in NATO. Considerable advance has been made to support the concept of “train as you fight or operate” by achieving close integration between simulation environments and command and control information systems. Key factors for the success of CAXes are the selected simulation, the level of training and competence of exercise planners and support personnel and the ability to mediate effectively between simulation and CCIS used by the exercising headquarters. For operational level exercises, the Joint Theater Level Simulation was selected as the preferred exercise driver. Effective methods for exercise planner training and simulation data base development have been developed combining clearly defined organisational concepts and tools. The methods of training have been refined but remain manpower intensive. Exercise management has been addressed more recently and is showing great potential for effective formalisation and support. Based on current practice and technological investigations, future avenues that will contribute significantly to this field are simulation composability through interoperability, advanced distributed learning and highly flexible data collection and analysis.

1 Introduction

The mission of NC3A’s CAX project is to support NATO’s Allied Command Europe (ACE) in the specification, development, implementation and evolution of a training and exercising organisation. This organisation will make use of the most advanced methods and tools available to perform its tasks of individual and collective training and exercising. Hence the emphasis on assistance by automated systems in the preparation, conduct, observation and analysis of training events.

An evolutionary methodology of systems development is applied which relies heavily on user participation and experimentation. Methods of organisation and work and supporting tools are developed and tested in a laboratory environment. Sufficiently successful prototype capabilities are subsequently applied during exercises. This phase of field testing is essential in evaluating capabilities with a broad user set under realistic performance conditions. The empirical data that can be gathered in this manner, forms the basis for the acquisition process of capabilities that will meet user requirements and will be able to continue to evolve.

The CAX development within ACE has gone through a process of laboratory development from 1991 to 1994, followed by extensive field testing from 1995 to 1999 and is currently transitioning into the acquisition of an initial capability through the creation of an ACE training organisation called the ACE Command and Staff Training Programme (ACSTP). Subsequently the organisational methods and supporting tools will evolve through short development, test and acquisition cycles.

This document describes the practice of computer assisted exercising that has been developed through the evolutionary process described above. The critical factors that determine the success of any simulation-

Paper presented at the RTO SAS Lecture Series on “Simulation of and for Military Decision Making”, held in Rome, Italy, 15-16 October 2001; Stockholm, Sweden, 18-19 October 2001; Virginia, USA, 23-25 October 2001; The Hague, The Netherlands, 10-11 December 2002, and published in RTO-EN-017.

driven exercising capability are introduced. The rationale for selecting the current model of choice for ACE and the associated management approach are discussed. Considerable effort has been expended on defining and refining an effective exercise preparation methodology and supporting tools. Current practice is discussed. In addition to simulation models, effective mediation with C2 systems employed by staffs during exercises is essential in achieving an environment that enables "to train as you fight". Proven methods and approaches will be highlighted. Finally, some major technological areas that can contribute to the evolution of a cost-effective CAX capability for ACE and NATO will be discussed briefly.

2 Overview and CAX critical success factors

In planning a CAX, it is critical to identify and describe the training audience in terms of their objectives. A clear definition of objectives in a co-ordinated manner among and within headquarters is essential in developing the expectation of the nature and of the results of the exercise. NC3A's CAX experts participate directly in the planning process of computer assisted exercises to ensure that achievable objectives are set and to inform exercise planners, participants and command groups of the capabilities and limitations of automated exercise support tools. This aspect of the planning process grows in importance with the number of headquarters involved in the exercise.

Having decided upon achievable objectives, the design of an effective information systems architecture that combines the simulation environment and the headquarters operating environment into a representative information management environment is critical. Locations, from which the training audience will be operating and the tools and systems that they intend to employ to communicate with their commanding and subordinate echelons, need to be considered. This aspect will have a direct influence on the nature of the communications systems that are used to enable data flow. The various options for the location of response cells to the lowest decision level of the training audience and the ability to provide automated interfaces from the CAX environment can be derived from this decision. Overall location decisions constitute an important cost driver for exercises and are therefore a critical aspect of the CAX planning process.

During a CAX, the real world is replaced by a simulated world. The simulated world's state, content and behaviour are defined by a combination of data and logic. The data is contained in the databases that form the input for the simulation(s) that contain the logic. Therefore it is necessary to ensure a direct involvement with:

(1) the development path and the developers of the simulation model(s) that are used for CAXes

(2) the definition of the data that is entered into the simulations.

Indeed, the data describing the simulated world needs to be a sufficient reflection of that part of the real world that is simulated to meet the exercise objectives. Since the objectives vary from exercise to exercise, this is an on-going task. In order to ensure formal participation by all parties involved in the process and allocation of sufficient effort, NC3A has introduced the concept of a CAX data base management team. The team combines representatives from the participating headquarters, simulation database experts and others who can contribute relevant knowledge e.g. geo officers, weapon system specialists etc. Each participating headquarters formally appoints a member of this team. They are trained by the CAX experts in the data requirements and the logic that the simulation applies to the data. The headquarters members tend to become CAX environment experts and need to become a part of the CAX management cell during the conduct of the exercise.

From an information systems architecture point of view, it must also be noted that data base building is inherently a distributed activity. The necessary means in terms of communication systems, data construction and review tools and data validation tools need to be available to support this way of working.

The simulation model or federation of models that supports a CAX consumes the data that has been built and can portray certain behaviours over time. It is a reduction of the real world and therefore will have limitations. On the other hand, automated simulations are very powerful in showing the impact of the environment, of limited perception of truth and of logistic constraints on the ability of units and entities to perform their missions. This is especially true when the environment is complex, the number of entities represented is large and their nature is diverse. If provided with good data, automated simulations can provide a consistent behaviour of entities and environment over time that cannot be achieved through other means.

Response cells constitute another critical element in a CAX. One or multiple response cells will communicate with a headquarters staff. Therefore a response cell must be viewed as a set of people and systems that communicate with the training audience as well as with the simulation environment. They must be able to provide relevant information to the training staffs and interpret their decisions in a realistic manner. Therefore they need to combine military and simulation knowledge. As a cell, they represent all the subordinate echelons below the training audience. Since the simulation environment may not be representing entities at a level of resolution that corresponds to the level directly below the training audience, a response cell must be able to develop plans and aggregate information over multiple echelons.

A response cell acting as a subordinate or another agency that exchanges information with the training audience may also introduce scripted events i.e. not simulated, in the sequence of simulated events when the circumstances are appropriate to meet specific training objectives. Ensuring a logical flow of events and a correct synchronisation is crucial when mixing scripted and simulated events. In view of the growing importance and reliance on automated CCIS interfaces, a function of response cells is increasingly being fulfilled by automated interfaces. These tools will generate data in a form that can be processed by the command and control systems used by the training audience and consume suitably formalized tasking from exercising staff.

Effective tools of the exercise directing staff are constituted by the cells representing the opposing and other forces that play an active role in the simulation database. These cells are tasked by the directing staff to achieve certain objectives. In order to increase exercise cost-effectiveness, professional cells employing powerful order entry tools are used to perform these functions. Another possibility is to oppose headquarters to each other. In this case, the structure of headquarters and response cell is mirrored. Small-scale exercises of this nature have been executed successfully.

Finally, the core planning team of the exercise must understand the above factors to perform its planning task. The team will also act as the main directing staff during the execution of the exercise. Therefore it is essential that this team receive sufficient knowledge about each of the exercise components. During the exercise, they must be capable of performing the following tasks:

(1) assessing the state of the exercise with respect to the achievement of exercise objectives

(2) determining effective measures to steer the exercise in the required direction e.g. by introducing external constraints like unexpected weather conditions

(3) understanding the factors that have contributed to the current state of the exercise.

These tasks require a lot of detailed information to be gathered and aggregated and a deep understanding of all CAX elements. Therefore CAX experts on each of the elements are assembled in a CAX management team during the exercise and are co-located with the main directing staff element. In view of the regular turnover of personnel, the knowledge transfer function to ensure that exercise planners are suitably trained to perform their function is essential.

It is also essential to consider the operational constraints that will influence the manner in which the CAX capability will operate. Affordable manning levels, funding for preparation and execution should be scoped prior to the selection of an exercise environment. Particularly the augmentation levels required for exercise execution can be prohibitive. Experience in NATO has also shown that professional support for response cells and communications assets to support distributed exercises in a robust manner are major cost drivers.

From an infrastructure point of view, the ability and need to achieve networking with C2 systems needs to be established. The ability to re-use existing communications infrastructure and support personnel is advisable. An approach concerning the provision of exercise-related expertise has to be selected. Indeed given the complexity of current exercise environments, the investment in acquiring subject-matter expertise is non-negligible. When selected, the personnel should be maintained in their role for a length of time that allows their knowledge to be applied sufficiently frequently and to be passed on when personnel transitions to other functions. In view of the regular rotations of functions in military organisations, this last aspect requires a well defined human resource management approach.

3 The CAX Model of Choice for Operational Level of Military Decision Making and evolutionary approaches

NC3A supports ACE in the selection of suitable simulation environments for its various and evolving exercising requirements. NC3A is also actively involved in guiding the evolution of these environments by capturing changing requirements, expanding current capabilities and fostering national or multi-national efforts. In this context, NC3A's CAX project manages changes to the Joint Theater Level Simulation (JTLS) and directs pathfinder activities in the area of multi-national simulation interoperability for exercises.

Complex simulation models contain a wide representation of entities and logical rules that describe the characteristics of real world objects and their behaviours. Hence designing the appropriate data to feed simulations and developing cost-effective modes of utilisation that meet organisational constraints, require an investment in time and the commitment of personnel resources to acquire the necessary expertise. Re-using a simulation environment for multiple exercises will increase the return on this investment. Therefore SHAPE decided to select a simulation environment for its operational-level exercises and to develop a small knowledge base to manage and maintain its investment at NC3A.

The principal factors that led to the selection of the JTLS model were:

(1) Its ability to simulate joint and combined operations including logistics and intelligence aspects at a level of detail commensurate with the intended training audience. The level of detail required by the various training audiences in NATO was identified using the level of detail of information required by the lowest levels of exercising staffs.

(2) The unclassified nature of its algorithms enables its application for exercises at various levels of classification in a NATO and PfP context.

(3) The lack of embedded data in the simulation code that enables multi-national systems and capabilities to be defined and configured by the model operators rather than by its developers or configuration managers.

(4) Its affordability in terms of licensing and operating cost.

(5) The acceptance by the model management organisation of SHAPE as a voting and contributing member in the development of the simulation.

As a member of the JTLS configuration control board, SHAPE participates in the yearly prioritisation of trends for modification and enhancements to the model. NC3A, as its technical agent, co-ordinates the inputs of suggested modifications throughout ACE commands and introduces them in the formal configuration controlled change process of the model. Specific modifications that are of high importance to SHAPE and cannot be funded by the configuration control authority are funded separately. Their implementation is managed by NC3A in close co-ordination with the configuration control authority.

In addition to the management of the JTLS model, SHAPE has fostered the co-operation between NATO nations in the CAX area by establishing an advisory multi-national working group. This group has enabled SHAPE to remain fully informed of national developments and has enabled new operational requirements to be presented and discussed. These interactions have resulted in the experimentation with multi-national federations of simulations based on various simulation interoperability protocols. The collaborative work has contributed to the development of a NATO-wide modelling and simulation (M&S) master plan and the establishment of a NATO M&S group. A sub-group has been initiated that addresses CAX matters specifically. This group, the NATO simulation advisory task group on CAX, has subsumed the work of SHAPE's multi-national working group and is chaired by NC3A. Simulation interoperability is currently perceived as the most cost-effective method of enhancing exercising environments. Particularly, combining proven exercise simulations to meet emerging exercise requirements allows user confidence to be maintained and reduces technical as well as exercise operational risk. However it must be recognised that this approach will require greater emphasis and resources for interoperability protocol management and evolution as well as for federation compliance testing. It also needs to be understood that interoperability in a multi-national context requires a sustained and substantial commitment by the participating nations and institutions.

4 CAX Preparation Methodology and Tools

As discussed in sections 2 and 3, the data that is utilised by the exercise environment is critical to the success of an exercise. It represents a considerable investment in time and effort on the part of the CAX data management team and of the nations and headquarters that have contributed to its population, verification and validation. Hence a formalised process is required to maintain the quality of the CAX data and tools are required to support its phases. Paragraph 4.1 describes a process that has been refined in recent years.

Equally paramount in the development a CAX is to ensure that headquarters can use their real world command and control systems. This requirement imposes constraints on CAX databases. It also implies the co-operation between diverse organisations managing exercise environment and day-to-day operational environments. Paragraph 4.2 describes an approach that has been applied successfully in ACE and that enabled complex and sometimes conflicting issues to be resolved in a timely manner.

Finally, the success of an exercise is highly dependent on the level of proficiency of its response cells in performing their part as role players, tasking and information management teams and simulation operators. Paragraph 4.3 addresses some of the issues related to response cell training and some of the approaches that have been pursued with varying levels of success.

4.1 Data base preparation

As discussed in section 3, the JTLS model does not contain data. Hence the population, maintenance and evolution of JTLS databases need to be a sustained activity. As forces re-organise and system capabilities develop, new entities need to be included in exercise settings and suitable system characteristic representation in the simulation database needs to be ensured. The task of data management is likely to become even more critical as simulation interoperability starts to deliver effective federations of simulations.

User ownership of data and the explicit need to invest time and effort in verifying and validating the quality of data used for exercises are at the centre of the organisational approach that has been developed by NC3A for ACE. Indeed the diverse nature of NATO forces, systems and tactical employment concepts, requires the involvement of experts of each nation in various military fields. As these activities require experts to allocate time to perform data collection and verification tasks and to travel to participate in validation efforts, it is necessary for authorities to recognise the need for the investment and to prioritise associated time and funds.

For each exercise, a CAX data base management team (DMT) is formally constituted prior to the initial planning conference. The typical composition of a DMT is listed below:

(1) A DMT co-ordinator provided by the headquarters that has the lead in planning the exercise. The role of the co-ordinator is:

- (a) to ensure the participation of all data providers in the data base building process by calling the various meetings and verifying agreed attendance;

- (b) to maintain an overview of the contents of the database and ensure that the conditions are being created that will support the achievement of stated exercise objectives. Of particular importance are the force ratios that are established, the capabilities of selected systems and the existence or lack thereof of specific high interest capabilities e.g. theatre ballistic missiles.

(c) to verify the joint aspects of the data base i.e. the complete force compositions and the respective strengths and weaknesses of services and sides which will lead to the need to co-operate during the execution of the mission;

(d) to co-ordinate the representation of non-military entities.

(2) For the selection of all air assets for all participating sides in an exercise, the responsibility is attributed to a representative of the air component command that is usually part of the exercising headquarters.

(3) A maritime and marine forces representative usually provided by the participating maritime component headquarters is responsible for the selection of all related assets including maritime air assets and ground-based sensors.

(4) A geographic data co-ordinator responsible for collecting the data that is necessary to develop the terrain data base

(5) A target co-ordinator responsible for all fixed targets represented in the exercise database.

(6) A representative of each major military formation that is represented in the database and that will be providing a response cell during the exercise. In-depth involvement of the formations in the database building process ensures that the capabilities of forces are suitably represented and validated. This approach prevents many problems that have been encountered in the past when the level of involvement was very limited and response cell personnel identified data inconsistencies in the final pre-exercise preparation phase. The formation representatives will call on support from specific subject matter experts and will assemble a validation team that participates in the validation phase.

(7) As most exercises are set in a fictitious context, a country-book representative is appointed to be part of the data base management team. The role of this representative is to ensure consistency between country book descriptions and data base contents. Active participation by the representative is particularly important in the early and final phases of the database building process.

Concerning the unit database building aspect, a side-orientated organisation of the database management team has been abandoned because it led to imbalances in side strengths and capabilities, which were incompatible with exercise objectives.

The establishment of a permanent data base management has been suggested to reduce exercise-specific data base building activities. ACE’s northern region is investigating the possibility to form such a group. The provision of exercise independent funding for this task may be a challenging issue and may need to be addressed from a more structural perspective. Indeed the establishment of an exercise data management organisation within the headquarters structure may be required to ensure sustained personnel and information systems support.

Over the last five years a process has been developed that consists of five distinct phases:

(1) An entity design phase, which covers approximately four to six weeks and starts approximately 9 to 12 months before the intended execution date of the exercise. Typically this phase will start after an initial planning conference has taken place.

(2) 2 data collection and verification phases. Each phase lasts for about 4 to 8 weeks. The phases are consecutive in time and start after the conclusion of the entity design meeting.

(3) a data validation phase, which covers 4 to 6 weeks. It follows the conclusion of the verification phases.

(4) a Startex validation phase which covers 1 to 2 weeks and starts approximately 6 weeks prior to the start of the exercise. Indeed all the important aspects of the exercise need to be well defined to make this phase effective.

The entity design phase starts with the formal appointment of representatives to the data base management team. Following some introductory briefings on simulation capabilities, the need is described to make a number of decisions concerning the modelling of the natural environment and of the entities that will populate the simulated world. Based on the NC3A team's understanding of the stated exercise objectives, a proposed set of entity designs is compiled and distributed to the DMT members. The phase culminates with a two-day meeting, whose objectives are:

(1) To refine the main database building decisions: detailed decision on geographical area and important features, number of sides, factions within sides, size of force and type of organisation, level of detail of forces and non-combatants, logistic concepts, C2 systems that will consume exercise data

(2) To conduct an initial review of the forces, target sets, unit types and logistic categories that exist in the core CAX database and in the archive of specific exercise database. These data sets are commonly referred to as "shopping lists".

(3) To re-visit and assign the specific responsibilities of each individual DMT member.

(4) To review and amend the data base building time line in order to ensure that it is synchronised with the participating headquarters operational planning process and to complete the process in time for Startex validation and for response cell operator training. The synchronisation with the operational planning process is critical to ensure that capabilities that may be identified as essential to the success of the selected course of action are actually suitably represented in the simulation's database.

(5) To identify areas of uncertainty in the definition of the exercise setting. Indeed the exact detail of exercise requirements may not be fully clarified at this stage of the exercise planning process. Ensuring that these design questions are identified and resolved early, is essential to achieve a successful exercise.

(6) To present the tools and data exchange procedure that will be used to exchange data between data providers and data base builders.

DMT members, representatives of host nations and the NC3A team of simulation and database experts need to participate in the design meeting. In order to facilitate the decision making process, it is necessary to limit the attendance of this meeting.

The decisions taken during the entity design meeting are fully documented including their rationale. The resulting document serves as a permanent guideline for data providers during the database building process. It is also very instrumental during the training of response cells. Indeed learning a simulation's functionality allows an operator to interact effectively with a simulation model. However understanding the reasons that have led to the representation of specific entities and capabilities, enable operators to use them actively to perform their tasks in a way that supports the implementation of the objectives of exercising headquarters.

Following the completion of the entity design document, a scenario database is initialised and distributed to DMT members for extension during the first data collection phase.

The success of the approach described above is closely related to the development of a reference or core data base and of an exercise data base archive. The core database contains verified and validated sets of units and system parametric data. The archive enables terrain and target databases to be re-used. Extensive re-use of data allows the process of database building to be tailored. Particularly the validation phase can be skipped when new system capabilities are not introduced in the exercise database. However data base preparation cannot be compressed too much. Several feedback phases of data and the Startex validation phase are essential elements in ensuring that exercise requirements and the means to achieve them are understood to a sufficient level of detail and have been configured to achieve an effective exercise.

The data collection and verification phases are organised as a sequence of:

(1) Data collection by the various DMT members

(2) Provision of collected data to data base building team for consolidation and interpretation

(3) Verification meetings between data base building team and DMT members to evaluate progress and identify remaining open issues.

The first phase of data collection focuses on ensuring that all relevant entities are identified and built. During the second phase, the detailed status of entities is emphasised, system characteristics are reviewed in a static manner. The consistency with country books is also verified at this stage.

The product of these phases is usually a database that contains all the entities that were agreed during the entity design phase and that enables the exercising of the outcome of the operational planning process. Experience has shown that it is advisable to develop a more robust force structure for all sides in an exercise setting to increase the ability to respond to late requests by operational planners and to be able to address emerging exercise aspects.

In order to facilitate the distributed data collection and verification, simple unit force structure creation, editing and documentation tools have been developed. They support DMT members in selecting and configuring the part of the force structure for which they are responsible. The tools have been designed to enable the data base builders to consolidate the data base inputs with limited manual intervention at their regular place of work. This approach is considerably more efficient than a paper or electronic form-based approach and is more effective because it reduces the error associated with multiple persons manipulating the same data item. Similar tools have been introduced for building terrain and static targets.

Having completed a static building and review process, the DMT can be assured that the simulated environment and entities have characteristics that correspond to their real-world equivalents. However the ability of entities to interact with each other and with the environment and the associated results cannot be verified by studying the characteristics in a static manner. A dynamic validation is required to address these issues. During this phase, the combination of simulation and exercise-specific data is subjected to a set of detailed tests. The validation phase consists of the following steps:

(1) Definition of test plans. A set of detailed tests has been developed to address each function that active entities need to be able undertake. Tests that are relevant in the context of the exercise are selected and suitably customised for the exercise database. As simulations and entities evolve in terms of capabilities, additional tests are regularly introduced.

(2) Assembly of test teams. DMT members assemble teams that have the necessary knowledge to assess the results of the tests. Reference performance data is also collected to support an objective calibration of the simulation database.

(3) An optional step, which has been very successful when we have introduced new capabilities, has been a pre-user validation session with simulation developers and external simulation data base experts. The ability to step through the events in the simulation at the simulation code level, provides a detailed understanding of the behaviour of all the entities that are involved in a test and allows the identification of the important factors that contribute to the achievement of a particular outcome. Including external data base experts during these tests enables a very effective exchange of experience and insights in the configuration of data to achieve expected results.

(4) Conduct of validation tests. Typically these tests are organised by functional area. They are conducted in a centralised manner bringing together database and subject matter experts.

Participants need to be trained in operating the simulation environment. Experience has shown that this requirement is not always met. It introduces delays in the validation process and increases the burden of analysis by the introduction of a higher frequency of operator error. Depending on the progress that can be achieved during these sessions of approximately 2 to 3 days, it may be necessary to repeat validation tests and to introduce an additional session. Documenting the test process in an effective manner remains a challenging activity especially when attempting to capture reference data also.

The product of the data base validation phase is a database that contains environment and entities that correspond to their real-world equivalents and are able to behave as such in the simulated environment.

In order to improve the quality of data, experiments have been performed with distributed data validation. Small-scale versions of simulation environments have been provided to headquarters in conjunction with training and test plans. Varying levels of success have been achieved principally due to the amount of effort available for local testing and due to the additional system management burden placed on local support teams. In order to alleviate this latter problem, a port of the JTLS environment to a Windows NT environment has been started.

An improved set of test definition, execution and documentation tools are under development.

The final phase of the database building process is the starting situation, or Startex, validation phase. The DMT members and the principal operational planners are brought together to attempt to predict the flow of the exercise. Obviously in a dynamic interactive simulation, the detailed flow of events cannot be predicted. However from a macro-level, the starting conditions should set the scene for the probable direction of the exercise and should enable exercise planners to introduce those elements that contribute to the achievement of the exercise objectives. This phase consists of the following steps:

(1) Detailed Startex setting. Operational planners are requested to describe the intentions and expected implementation of their plans and to set the detailed starting conditions in terms of force positioning, attrition levels and other starting conditions.

(2) Simulation of exercise flow. The exercise planners and DMT members confront the selected plans to the intended activities of other entities and particularly of potential adversaries using the simulation environment with aggregated order sets and at a very accelerated time speed. Several iterations are usually required to achieve a satisfactory starting situation.

The validation session is usually held at a central location or at the primary headquarters location and covers a three-day period. It enables a good assessment of the exercise starting conditions and forms the basis for the CAX management efforts during the execution of the exercise. In order to facilitate the generation of aggregate order sets, tools have been introduced that allow sequences of orders to be defined and executed without manual intervention.

The approach and tools described above have been refined over the last five years and have for the last three years produced consistently well performing data bases in the JTLS environment. Further efficiency improvements are possible as well as effectiveness enhancements, however it needs to be pointed out that data base development is a process that follows and stimulates the exercise design process and as such cannot be excessively compressed in time.

4.2 CAX-CCIS Architecture

An important operational requirement for headquarters collective training is the ability to employ the operational communications and information systems tools that support the operation of and between headquarters. This ability is often referred as “train as you fight” or “train as you operate”. Fulfilling such a requirement implies close co-ordination between exercise and CIS planners. Indeed the CAX and CIS architectures need to be designed and configured as a seamless environment for the exercise to permit the effective transfer of data in both directions. The need to meet security regulations must also be addressed and suitable provisions need to be made to ensure confidentiality of exercise and real world data.

In order to manage the joint CAX-CCIS architecture design and implementation process, NC3A has introduced the concept of a CAX-CCIS architecture group. The principal CIS planner for the exercise leads the group. Representatives of all participant headquarters contribute to the group. In order to ensure the support of the CCIS support organisations, they are requested to participate actively. NC3A acts for NATO as the management organisation for the set of tools that mediate between simulation environments and NATO command and control information systems.

The architecture group has an important configuration management function in the sense that it needs to determine at an early stage of the exercise planning process which versions of information systems will be used by headquarters and which operational communications networks can be employed to support CAX-specific and operational exercise data. Version management applies to the introduction of new releases of simulation environments, mediation-ware and C2 applications. The selection of the versions needs to be taken into account during the database building process. Indeed the exercise database needs to take into account any data-related constraints that are imposed by C2 applications. Otherwise the applications will not be able to be initialised with exercise without a considerable amount of conversion effort. The data constraints apply to the complete range of data sets that are developed for an exercise including terrain, targets, units and system performance characteristics. Close co-operation between data base builders and C2 application designers is the most effective manner to identify the complete set of data constraints.

During the preparation phase of an exercise, modifications and potential enhancements to mediation modules are identified. They may be necessary to leverage new simulation capabilities or new C2 application functionality. Enhancements are implemented if the architecture team assesses that there is sufficient effort and time available to perform the following steps:

(1) Develop a detailed design of the required features. The operational users of the C2 applications as well as their technical support organisation need to work with the NC3A development team to perform this task. Inevitably priorities will need to be set.

(2) Implement prioritised features

(3) Perform technical testing of the modified mediation features. These tests involve the NC3A mediation-ware development team and the technical support organisation of the particular C2 application.

(4) Perform operational testing. Using preliminary versions of the exercise database, the technically tested features are submitted to an operational evaluation. Typically a number of representative and relevant situations will be executed with the complete simulation, mediation and C2 environment.

(5) Produce and submit modified security accreditation documentation. This step needs to be scheduled carefully in view of the timelines that are needed by accreditation authorities to study new features and to grant their approval.

(6) Prepare training material for response cells and operational C2 application users. Indeed mediation-ware may require specific rules to be adhered to in order to perform its function. This is particularly the case for mediation ware that interprets plans and transforms them into a set of simulation orders.

The aspects of mediation that need to be considered are:

(1) Initialisation: the ability to transform relevant simulation data base data into the appropriate format that can be used by the C2 application.

(2) Reporting: the ability to extract relevant data from the simulation environment to provide status or event updates. Typically this form of mediation is achieved through messages that comply with prescribed formats or through database to data base updates.

(3) Ordering: if the plans that are developed by the headquarters are sufficiently formalised in the supporting C2 application, the potential exists to employ automated mediation to transfer these plans into orders that can be executed by the simulation environment.

Currently, the mediation-ware that is used for most major CAXes employs the Joint Theater Level Simulation as its principal data provider and consumer. In order to increase the flexibility and modularity of the mediation architecture, a model independent information exchange layer called the Operational Environment Simulation (OES) database has been defined. Through a number of clients, simulation data is entered into and extracted from the OES database. The OES database encapsulates the JTLS model. Hence any environment capable of generating and consuming the data contained in the OES database could be employed to support the current information flow. A formal report generator, a Maritime CCIS (MCCIS) mediator and a set of Initial Combined Air Operations Centre (ICC) modules complete the mediation process.

The actual mediation-ware that is employed during an exercise is primarily dependent on the level of utilisation of the C2 applications within the exercising headquarters

4.3 Response cell composition, training and tools

Response cells are a major cost driver for exercises. They also constitute a critical success factor. Hence the challenge of the exercise planning team is always to achieve the greatest cost-effectiveness by designing cells that are affordable in size, that have the appropriate composition and that do not require an excessive amount of time for training.

Several approaches can be considered with different merits and associated cost-effectiveness:

(1) Full augmentation: cells are fully manned by augmentation personnel supported by one or two simulation experts. This approach is usually applied for large exercises that are executed on a 24-hour basis with response cells operating from various distributed locations. In order to transfer the knowledge that is necessary to operate the simulation environment effectively to the large number of augmentation personnel a three-step approach has been applied successfully. The first step consists of a one-week familiarisation with the simulation. Formal briefings and hands-on sessions are alternated followed by a mini-exercise. A scenario is used that is not necessarily related to the exercise. The second step is a two-week train-the-trainer session. During the first week, response cell trainers are instructed in the detailed operation of the simulation using the database that will be employed during the exercise. During the second week, the focus is placed on how these trainers will convey their knowledge to the rest of the augmentation personnel who will form the response cell during the exercise. The third step is response cell training just prior to the exercise. As a result of experience, this phase comprises an operator training phase of three days, 1 day of operator mini-exercise and two-days of complete response cell mini-exercise. The exercising headquarters do not participate in the mini-exercises to avoid confusion and to be able to focus on response cell objectives rather than staff goals.

During the last three years, the limited simulation environments that were installed in headquarters to support the validation of the exercise database have also been employed by response cell trainers to train augmentation personnel from their headquarters. Cells that were prepared in this manner displayed a considerably better performance than other cells.

(2) Mixed professional operators and augmentation: this approach combines professional operators who manage and task entities with augmentation personnel who are able to retrieve relevant data and who monitor progress in the simulation. It has been applied very successfully for small-scale exercises where a limited number of operators are capable of managing the entities

that are active in the simulation. Due to their background, training of professional operators is not required. Augmentation personnel are principally instructed in data retrieval tasks and monitoring tasks environment. A three-day session prior to the exercise is employed to convey this knowledge. The final preparation that precedes the exercise serves primarily to introduce the operators to the exercise database and scenario and to perform a 1.5 day operator mini-exercise. During this dedicated mini-exercise, the important phases of the expected exercise flow are executed. Finally a one-day mini-exercise is executed with the complete response cell including the planning and reporting element that does not need to interact directly with the simulation environment.

It must be noted that the term response cell used above applies to all exercise control components including directing staff and other forces cells.

Experiments have been conducted during exercises with automated tools capable of performing order amplification and information aggregation to investigate potential reduction in training time and complexity and to study reductions in cell size. Due to the technical complexity of these tools and limited development resources, work is continuing in this area and experimental results have not yet been conclusive. Powerful data visualisation techniques, algorithmic approaches and artificial intelligence-based concepts are combined to develop these capabilities.

5 CAX Conduct

5.1 CAX-C2 mediation

NATO information flows make extensive use of formal reports formatted in accordance with published specifications (Bi-SC reporting directives, AdatP3, local directives). The Formal report generator combines data from the OES database with format definitions to create text files. Depending on the physical implementation of the link between JTLS and the HQ's messaging system, reports can be emailed to selected stations or passed to a military message distribution system. If required, the message header can comply with the ACP127 format, enabling distribution based on Subject Indicator Codes.

Report Generation can be triggered in three ways:

1. Periodic Reports. The report is automatically produced at specified simulation times.

2. Event based reports. The report is produced when a certain event happens in the simulation e.g. the detection of an enemy unit

3. Requested reports. The production of a report can be triggered manually by entering its type and originator at the report generator workstation.

It must be noted that only factual information can be drawn from the OES database and the simulation model. Report fields that require human judgement or assessments cannot be produced. Response cell personnel need to add this data. Also, some factual information may not be available from the model such as the primary and secondary task of a unit, its echelon, its OPCOM/OPCON status etc. The most effective use is for response cell to edit the reports and add relevant data. If messages are automatically passed to the C2 systems, these missing data items will appear blank (or some default value) in the CCIS system's database.

The JTLS-MCCIS Mediation-ware is an example of an implementation where formatted messages produced by the report generator are sent to and automatically processed by a CCIS system. OTH GOLD contact reports are sent at regular intervals to MCCIS causing the Recognized Maritime Picture (RMP) to update its set of simulated tracks automatically.

In addition a utility exists which can convert a JTLS user line file into an OTH GOLD overlay message (OVLY). Response cell created graphics can be passed to an exercising headquarters' MCCIS as an overlay to convey additional information.

ICC is an integrated C3I environment that provides information management and decision support to NATO Combined Air Operation Centers (CAOC). The ICC provides functional support for the most critical Air C2 functions at the CAOC level, such as Planning & Tasking, Air Task Order (ATO) and Mission monitoring.

The ICC – JTLS Mediation-ware provides the CAOC's the possibility to use their own C2 System during JTLS exercises. The mediation-ware is bi-directional. Data is retrieved from ICC into JTLS (tasked missions). JTLS data is inserted and updated into ICC (e.g. mission reports).

The ICC – JTLS Mediation-ware contains 4 modules:

(1) ICC Initialize module: This module extracts relevant data from the JTLS scenario database and translates it to the ICC database e.g. aircraft characteristics, air defense sites, radars and (enemy) targets are stored in an ICC exercise database.

(2) ATO compiler: The CAOC's plan an ATO in ICC. Once released, the ATO compiler translates the ATO from the ICC format to JTLS orders. These orders flow into JTLS.

(3) ICC update module: Once a compiled ATO is read into JTLS, data can be sent back to ICC. Mission flight information, reports and analysis as well as status of squadrons, airbases, air defense and radar sites can be kept updated in ICC.

(4) ICC track Formatter: JTLS track data is transformed and sent to the ICC workstations enabling a Recognized Air Picture (RAP) to be shown on ICC's ADAPI tool. A link exists between tracks and mission data to enhance RAP monitoring.

Several methods can be distinguished to pass information from the OES database to a CCIS system:

(1) Direct database to database connection. In this method, an interface process copies data directly from tables in the OES database to tables in the CCIS system's database. This is done in the case of the ICC interface.

(2) Formatted messages, automatically parsed by the receiving CCIS system. Data from the OES database is formatted according to specified rules and transmitted on a designated channel (email, tare, direct connection) to the CCIS system where it is automatically processed. The MCCIS interface is an example of this method.

(3) Formatted messages, parsed by operator intervention at the receiving CCIS system. Similar to the previous method but an operator has to take some actions to absorb the information in the CCIS system.

(4) Formatted messages only.

In addition to a data base driven approach to mediation, NC3A and the US Defense Modelling and Simulation Office (DMSO) have developed a mediation solution for JTLS, to communicate with ICC, MCCIS and the report generator according to the specification of the High Level Architecture as shown above.

The mediation-ware has been refined over the last 4 years. It has allowed the size of air response cells to be reduced and has greatly contributed to the refinement of headquarters way of using C2 applications by enabling their utilisation on a scale and intensity that cannot be achieved through other means.

The impact of using direct interfaces between simulation and CCIS is the need to have greater validity. Indeed, discrepancies between simulation and real world become almost immediately apparent to the training audience e.g. an automated maritime picture display is updated automatically and will show the disappearance of a ship in an almost real time manner. Hence it must have a valid explanation. With the growing formalism given to instructions between headquarters and subordinates in C2 systems, prototype interfaces have been developed by NC3A that are capable of transferring these orders into the simulation environment without manual intervention. Work in this complex area is on going.

5.2 CAX management

From an organisational perspective, a method has been developed and applied successfully that turns the team that has prepared the exercise database into the CAX management cell for the exercise. Indeed these persons combine a deep knowledge of the exercise objectives, of the courses of action and expectations of operational planners, of the simulation model and of the simulation data that has been engineered to support the achievement of the objectives. Co-located with the core of the directing staff they can monitor exercise progress and advise on any immediate or other important exercise control decisions.

One of the tools that are regularly employed for exercise control co-ordination is Video Tele-Conferencing. (VTC) Following a formalised cycle of meetings, typically two per day for 24-hour exercises, this method of distributed meeting has proven to be effective. The main factors that contribute to its success are the high degree of co-operation that the tool promotes through its increased information content compared to a telephone conference and the need to confer in an organised and disciplined manner. The objective of the VTC meetings is to address exercise control issues from an exercise operational and from a technical perspective. The leaders of all the exercise control cells participate in the meetings and contribute their impressions. This approach enables a strong team spirit to be achieved even though members are distributed over large distances.

For the management of more detailed questions that are raised by members of exercise control cells, a procedure of electronic mail exchange with the CAX management cell has been developed. This approach is to be recommended over other approaches because it enables the following essential CAX management aspects to be addressed in a very efficient manner:

(1) When reporting a suspected issue or problem, cell operators have the ability to cut and paste actual simulation data into their message. The CAX management receives the detailed information that it requires to investigate the reported problem and can respond with an equal level detail. Compared to a telephone, note taking and third person input into a problem management tool, this approach offers great advantages.

(2) Messages can be organised by sending cell and sub-organised into open and closed items. Most modern messaging environments support the management of message flows using custom folders. Furthermore timeliness of responses can be tracked and responses that may be of interest to multiple cells can be propagated very easily.

(3) The level of importance and criticality can be indicated in a message characteristic or subject header enabling rapid selection and retrieval by members of the CAX management cell.

(4) Finally CAX management team members do not need to react in real time to incoming requests in a way that is required when problems are reported using telephones. This efficiency gain is quite considerable.

Although having instituted an effective method to manage and act upon reports of suspected problems is critical, CAX management can be greatly improved if problems can be anticipated, studied and remedied before they become apparent to the exercise control cells. Obviously the overall objective is to ensure that problems, either real or perceived, do not become apparent to the exercising headquarters. The most important classes of reported problems are either related to parametric data or to events being considered as inconsistent with exercise objectives or as an unfair usage of simulation features. In order to address this problem domain, NC3A has developed and experimented with a set of tools that monitor simulation events and provide aggregate views of the state of the simulated world. Concerning the monitoring of critical events, exercise experimentation has shown that perceived problem issues are often related to two areas:

(1) High levels of attrition over a very short period of time: important losses to army formations over short periods of time can impact the execution of the course of action selected either by the exercising headquarters or by the exercise control cells responsible for other forces than those managed by the exercising headquarters. The CAX management cell has been equipped with a number of views that depict losses over time and sort them by most important victim over a selected time frame. These tools have enabled the CAX management cell to become aware of the impact of losses more rapidly than the cells that are actually managing the forces.

(2) Attrition to high value assets: typically in the airforce and maritime areas, assets which are considered and perceived to be highly unlikely to be the subject of attrition by exercise control personnel are monitored by class. Attrition is flagged instantly and associated causal data is assembled in a processed form.

Combined with an ability to analyse the reasons for the attrition, an assessment of the causes can be made rapidly. Potential courses of action can be evaluated and acted upon before the problem is actually raised by the cell that is managing the affected forces. The ability to anticipate problems and to provide detailed descriptions of the causes of events, contributes greatly to the stability of the exercise environment.

It should be noted that the close integration between simulation and C2 systems increases the need for close monitoring of events and for the availability of a capability to trace the causes of specific events, even more.

From an aggregate exercise management perspective, a very important step in managing a CAX effectively is the definition of a scenario flow reference. This reference data is built up and validated during the Startex validation session. An expected flow in time and space for the exercise is developed as a result of the session. The flow in time and space is expressed using a set of aggregate measures, which are collected during the exercises. The comparison of intended and actual exercise flow enables the CAX management cell to assess exercise progress from a macro perspective and greatly reduces the tendency to react to individual events. Indeed the intensity of exercises, during which many events that would normally take place over longer periods of time are concentrated and during which carefully laid plans are sometimes gravely disturbed, can lead to a tendency to react very negatively to adverse events. The ability to maintain and visualise the “big picture” is the most effective tool to counter such situations.

5.3 Observation and analysis

Currently observation and analysis from a CAX perspective is primarily focused on the simulation environment. Co-ordinated and combined observation of simulation and operational environment has not yet been addressed although the need to do so is recognised. The tools that are discussed in the previous section and that are very effective for real-time CAX management are currently also the main tools that are employed for after-action analysis.

6 Future Needs

The experience that has been gained through exercises and experiments over the last ten years in the field of CAXes that focus on the operational level of decision making has been discussed in the previous sections. Great methodological and technical progress has been made. However requirements continue to evolve and expand. At the same time, the pressure to use available personnel and financial resources in an ever more efficient manner continues to increase. Together they pose considerable challenges to the developers and operators of simulation environments. This section will discuss some of the technological avenues that might be considered to meet these challenges.

6.1 Simulation composability

Over the last ten years, aggregate simulation interoperability as well as entity level simulator interoperability have developed considerably and have been used for operational exercise support purposes. Many of the problems associated with the utilisation of networks of simulations and simulators are understood. Interoperability protocols for these two domains have been merged in the specification for the High Level Architecture (HLA). Recent experience shows a trend in combining simulations to meet specific exercise requirements rather than expanding individual simulations. A major factor in this trend is the need to combine different levels of detail. As aggregate simulations would need to be modified considerably to provide the required level of detail in some areas and detailed entity-level simulations cannot manage the size and number of entities required for an aggregate scenario, the temporary combination of the simulations appears the most cost-effective solution. For more elaborate confederations in which many different simulations participate, issues of data base preparation, response cell training and exercise management need to be studied further. Concerning the area of preparation, validation of data that is used across simulations and validation of effects of systems needs to be addressed carefully. From a response cell preparation perspective, the training of augmentation personnel needs to be investigated particularly in the case that operators may be interacting with multiple simulations. Finally managing a federation of simulations in a manner that was discussed in the previous section needs to be studied. Indeed it is highly likely that data that is exchanged between simulations will not provide sufficient data to support the exercise control process as discussed in the previous section.

Anticipating meaningful combinations of levels of detail and identifying associated sets of simulations can greatly contribute to the ability to meet exercise requirements within the 12 to 18 month planning cycle of an exercise. Indeed attempting to reduce the amount of time required by the proven technical process of interoperability development and testing to fit within an exercise planning cycle, should not be advocated. The increased technical risk and likely problems and failure during exercises can only detract form utilising this very cost-effective approach.

Further combining interoperable simulations with C2 mediation and intelligent agents capable of reducing exercise control cell personnel requirements appear to be effective avenues.

One of the key factors of success for this type of approach is the commitment of sufficient resources to the management aspect of federations of simulations, C2 mediation and intelligent agents. Indeed the management of interoperability agreements, the certification and testing of federations and the management of their employment needs to be properly resourced in order to provide longer term benefits.

6.2 Advanced Distributed Learning

As discussed in section 4.3 training of exercise control cell personnel is a critical aspect for the success of any computer-assisted exercise. The regular turnover of military personnel requires a continuous approach to training. As pointed out in section 2, this training must start with exercise planners. In view of the distributed nature of the training and the availability of reliable digital communications between headquarters, the expanded usage of computer-based training tools and distributed interactive capabilities needs to be explored and leveraged. Efficiency gains due to reduced travel time requirements and effectiveness improvements associated with more extensive and verifiable training opportunities are the likely benefits.

The same technologies can be applied for augmentation personnel training although the ability to communicate with them may be reduced. Indeed augmentation personnel may not necessarily be reachable through secure digital communications networks. Training across public networks should be considered and investigated.

6.3 Observation data collection and interpretation

Finally an area that remains to be developed considerably is the structured analysis of performance of collective training during CAXes. The process of deriving data collection requirements from exercise objectives and aggregating group behaviour into representative measures of performance that can support the assessment of a headquarters ability to conduct certain missions needs to be improved and facilitated significantly. In particular it is considered essential that data collection and correlation inside the combined simulation and C2 environments be implemented to achieve this objective. The environments need to be instrumented in such a manner that meta-data can be collected and can be related to each other thus enabling events and problem situations to be monitored from their inception to their resolution.

The provision of an objective methodology and supporting tools to perform effective collective performance measurement is necessary to support the development of training doctrines and standards for NATO headquarters and partner nations.

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Computer Generated Forces - Background, Definition and Basic Technologies

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Abstract

The paper starts with some background information on the requirements regarding the use of Computer Generated Forces (CGF). The term itself will be defined based on a definition already given by the US DoD. Basic or relevant technologies are described and an overview on their development given.

1 Introduction

1.1 Background/History

The end of the Cold War has brought new military tasks and types of operations to NATO. These include regional contingency operations, Crisis Management and support of non-NATO missions (UN, PfP, WEU, etc.). All these have to be executed in a new environment with reduced forces and decreasing military budgets. The new geopolitical situation with expected reduced command levels and the need to co-operate between services as well as between nations, call for new concepts and systems.

Modelling and Simulation can be used as a tool to support the development of new concepts and systems for the future. M&S also help to better train and use existing forces and equipment and to improve operations in a new environment.

Emerging technologies will have a great impact on the implementation and on the military use of such simulation systems in the future. Computer Generated Forces as representations of forces in simulations which attempts to model human behaviour play a main part in this development. They offer support in different application areas; examples are thinking automated opposing (training and exercise), closed simulation systems (defence planning), Decision Support Tools (operations), and virtual environments (acquisition and procurement).

1.2 Present Situation

Computer Generated Forces are still used to some extent on lower levels of command and on weapon system level (e.g. Semi-automated forces). However their behaviour is stereotyped and only very simple levels of decision-making is addressed. Another approach for specific low level decision modelling is to use genetic algorithms. They are well suited for some optimisation problems, but are not sufficient to be used as a general tool for modelling human decision-making in simulations.

Paper presented at the RTO SAS Lecture Series on "Simulation of and for Military Decision Making", held in Rome, Italy, 15-16 October 2001; Stockholm, Sweden, 18-19 October 2001; Virginia, USA, 23-25 October 2001; The Hague, The Netherlands, 10-11 December 2002, and published in RTO-EN-017.

In the short-term “Higher levels of command“ are considered for Army company/battalion or Marine Corps platoon/company level. For these levels programs are launched to develop so-called Command Forces (CFOR program in US).

On the higher levels of command at and above brigade at the moment Computer Generated Forces are available, that is not mature and could be used only for specific application areas (e.g. closed simulation models with decision tables in Germany).

CGFs are of considerable use in the areas operations and acquisition and procurement.

For military operations e.g. they could be used within operational C3I-systems to help decision making by modelling own decision processes and simulating the enemy as thinking opponent.

In defence planning as well as in acquisition and procurement Computer Generated Forces could be used as tools in building-up simulation systems to lay-out force structures and individual weapon components taking into account doctrines and tactics.

In supporting Computer Assisted Exercises (CAXs) CGFs could be used in the Response and White Cells and for the representation of a Thinking Opponent. This use will help to save money and personnel drastically.

2 Definition of CGF

The definition of CGF for LTSS/48 is mainly based on the definition given in the US DoD Modelling and Simulation (M&S) Master Plan. This definition read as:

“A generic term used to refer to computer representations of entities in simulations which attempts to model human behaviour sufficiently so that the forces will take some actions automatically (without requiring man-in-the-loop interaction)".

Modelling and Simulation (M&S) Master Plan
US Department of Defence Oct 1995

The term “forces“ in the definition of LTSS/48 is not restricted to military forces, because of civilian engagement in crisis and conflict scenarios. This term is defined as:

“Military entities as they are used in conflicts, peace support operations, and other engagements [operations] like disaster relief, and other civilian entities and individuals as they are engaged in actions represented in the simulation system.“

The distinguishing characteristic of CGFs is automatic decision making. For example, a manned simulator without a crew is not a CGF. It has no automated manner to act on the synthetic battlefield. Adding a human crew also does not make this simulator a CGF. In contrast, if a computer program that commanded it autonomously supplemented the tank simulator, this would now be an example of a CGF. In the context of constructive simulations (e.g. in an exercise using a simulation model) a battalion whose behaviour is determined by the computer may be viewed as CGF, though its quality is a matter of degree. If a human operator controls the battalion, the battalion is not a CGF.

The degree of automated behaviour can span a large range within this view of CGFs. Some applications will need relatively simple representations of decision-making, while in others the requirements are more severe.

3 Relevant Technologies

3.1 Introduction

This chapter is concerned with the five technology aspects that are most critical to the use of CGFs to reduce costs while at the same time increasing the quality of the application areas Training & Exercises, Defence Planning, Operations and Acquisitions. The classification of technology areas to support these applications is of course somewhat arbitrary, but the LTSS study group as a natural one quickly agreed upon the choice used here. It served the dual purpose of (hopefully) being instructive to the reader and was assumed to be productive to study group process. As far the latter objective was concerned, the group process showed that one class, namely Systems Science/Architecture, developed into mainly dealing with the architecture and modelling of CGFs. Consequently, a new group was formed dealing with (computer) Architecture.

The technology areas are defined in each of the respective subchapters, and are:

(1) Synthetic Environments

(2) Architecture

(3) Modelling of CGF

(4) Human Behaviour Representation

(5) Human/Systems Interactions

While 1 deals with the physical scenarios of CGFs, 2 deals with how to organise CGFs so that they communicate well between them and their environment. 3 and 4 deal with respectively the modelling of CGFs in general, i.e. the interaction between the virtual human and virtual physical entities. 4 discuss the methods for representing and modelling the outcomes of what in the real world are human behaviours and related decision processes. 5 investigate technologies for interfacing the CGF with a human decision maker or other operator.

3.2 Synthetic Environment

3.2.1 Definition

The LTSS working group on CGF derived a definition (based on the US DoD definition) for Synthetic Environments in the following terms, modification shown in underline:

> Synthetic Environments (SE), "*Internetted simulations that represent activities at an <u>appropriate</u> level of realism from simulations of theatres of war to factories and manufacturing processes. These environments may be created within a single computer or over a distributed network connected by local and wide area networks and augmented by realistic special effects and accurate behavioural models. They allow <u>interaction and</u> visualization of and immersion into the environment being simulated*".

The first modification reflects that a Synthetic Environment should only be represented to an appropriate level of detail required for the particular application domain. The second modification is the recognition that the Synthetic Environment allows the realistic interaction of CGF components rather than just their visualisation.

3.2.2 Content Requirements

The content of synthetic environments can be broadly categorised into three main components: the terrain itself and its representation, meteorological and illumination effects, and so called "man made" effects such as artificial objects and human caused changes of terrain features.

3.2.2.1 Terrain

(1) **Terrain Representation**. How should a synthetic terrain database be represented? Using TIN (triangular irregular network) is a convenient method of representing terrain because in real life terrain does not neatly form itself into a regular triangular grid with a fixed diagonal orientation. But this is more computationally expensive.

(2) **Micro Terrain**[1]. Could micro terrain representation be used when dealing with terrain features local to entities and using a coarser representation at distance, considering the effect on units using high level resolution.

(3) **Database Generation**. Inevitably, these databases need to be generated for the particular areas of interest. Currently, this is very time consuming, as much manual labour is required to ensure consistent and realistic databases. As part of the US ASTT (Advanced Simulation and Technology Thrust) programme, ways of automating this process such that databases can be ready in 8 hours are being researched.

3.2.2.2 Meteorological, Illuminants

(1) **Weather**. The effect of weather can play an important role during operations. Not only does it have an immediate/direct effect (visibility, performance of equipment), but also a time dependent effect by changing the state of the terrain (rain making ground bogging, which eventually dries out again). Thus considering at the entity level, weather affects physical characteristics (such as trafficability, speed, etc), sensory systems (such as sights, laser and so on) and human behaviour (such as temperature effects).

(2) **Illumination**. The terrain can essentially be illuminated by a number of sources: the sun, the moon, flares and lights. Although relatively simple to model solar illumination, other sources are very important especially at night, when night vision or infrared detection systems are employed. Much harder to model (and display on a monitor) is glint from a reflective surface (e.g. a pair of binoculars), which is usually generated from a small surface, at some distance and is highly angular dependent. Glint from a vehicle is a major attribute to detection of hidden vehicles.

(3) **Sea state**. This generally has concentrated on the land-sea interface (the surf zone), however the effect of sea state is important for Maritime operations. For example, the sea state affects sonar performance (mine and submarine detection), bottoming out, communications, and so on. The depths of seas are seen to be part of the terrain description.

(4) **Air state**. Similar to sea state, the state of the air has performance on radar, aircraft performance and so on. This implies detailed modelling of cloud, air content, air currents etc.

(5) **Other**. This covers other types of effect such as smoke and chemical clouds. Deployment of smoke is a very important operational tactic (e.g. obscurant), and as such requires representative modelling.

3.2.2.3 Artificial Objects and Effects

(1) Dynamic Terrain. In real battles the terrain is altered either by consequence (shelling, detonations) or by design (protection such as ditches, trenches, etc). These effects cause changes to the terrain surface (craters) or to objects (destruction of bridge), or to both (road damage). In the case of the terrain, the representation needs the ability to be modified to reflect the change. In the case of the objects, these need to have multiple states (especially trees!), or for complex

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[1] Normally the terrain surface is represented as a regular grid of spot heights (e.g. 125 m intervals). However, in some applications it is necessary to resolve the skin at a higher resolution in some areas, for example to represent a bunker (e.g. 10m), in which to place a tank.

objects multiple states of sub-objects (e.g. rooms in a building). This is a hard problem, because the change must reflect on all instances of the database. Are the changes computed on a central database server then farmed out to the various simulators? Or, perhaps adopt the HLA philosophy that simulators register to a central database server their areas of interest. In any case traffic is passed over a network. It must be ensured to reach its destination and in a causally correct fashion.

3.3 Simulation System Architecture

3.3.1 Introduction

This Working Group was created in response to the recognition that there is more to military simulation systems than the important content of the CGFs themselves. CGFs are only meaningful within a context that includes an entire simulation (or operational) SYSTEM: the CGFs, the MMIs, the Synthetic Environment, the human behavioural models (HBMs) and other components discussed more fully in Section 2. Although CGFs may indeed be useful in a number of applications not requiring all of the above components, many of the future uses of CGFs will involve applications requiring the integration with live systems (e.g.C4I), the incorporation of multi-modal man-machine interface devices, the flexible combination of different CGFs, and the embedding of the CGFs into very different types of synthetic environments. The issue here is to not just develop an architecture that can allow reasonable interoperability of today’s CGF components and capabilities, but rather to set down the framework and issues in order to create an appropriately flexible and open architecture for the future wide-ranging applications of CGFs. Part of the required flexibility and openness is not only for the economic and scientific benefits of quickly building CGF applications out of existing, diverse components, but also to give different countries the flexibility to participate to the extent that they want to in different applications, while still retaining the advantages of leveraging off of each others’ investments and developments in this area. This is an important part of the strategy for leveraging off the commercial marketplace while retaining the requirements for specialised military systems; flexible architectures allow commercial partners to participate to different degrees.

Based on the collective experience of the team, we started with some important assumptions about the type of requirements we will need for a sufficient simulation architecture for CGFs. (listed below) We then spoke to each working group about the system level architectural issues from their point of view, and used that feedback to adapt our conclusions and recommendations.

This Working Group was chartered with describing the important architectural issues in developing such a simulation system, and identifying which of the long-term goals of the 1.Section (Application) Working Groups need to be addressed as system architecture issues. We also made some starting assumptions because of our experiences in large-scale architecture development:

Architectures must be specialised not only by task and domain, but also by specific classes of users.

Successful architectures have to be driven by customer pull as a well a policy push otherwise they will become obsolete due to economic forces.

Heterogeneous communities may require different architectural services with different constraints at each layer. Appropriate incentives can help individual and groups to see co-operating in shareable architectures as an advantage; the shared infrastructure and reusable components must be harvested, and made easy to use and access globally

Good simulation architecture should increase object reuse, decrease system risk, time to insert the technology, and eventually model development and maintenance costs.

Interoperability is matter of degree, depending upon the needs of the simulation, training, and C4I communities.

A simulation object repository provides information on objects, their public attributes, associations, interactions, level of resolution, and key models and algorithms used to represent entities in the simulation.

Simulation architecture needs common transport layers, common messaging systems, and neutral data formats to provide limited interoperability and maximum flexibility. This will allow commercial companies and developers to gradually “buy-in” to joint applications.

Systems integration at the communication level is a necessary but insufficient goal. Semantic integration via common ontologies is the critical challenge.

Selection of open architecture and protocols needs to track trends and standards in the commercial world in order to leverage off commercial investments for specific military uses.

3.3.2 Architecture of Simulation Systems

Architecture is critical for rapid construction and reuse of simulations and simulation components, because it defines the roles and responsibilities of the components in the larger system, including not only their interfaces with each other but also the semantics of their expected interactions. It allows those roles to be abstracted, so that other modules or components can be used instead, provided they perform the same roles and carry out the same responsibilities. This feature allows interchange of different components among different systems when the usage specifications agree.

The question is not *whether* to have an architecture. There is always an architecture when there is more than one function computed. The question is whether to make the architecture *explicit*, so that it can be designed and studied like any other part of a complex system. It is important when we use simulations to make informed decisions that we know what the effects of the architecture on the results are. Furthermore, we want to increase the flexibility and as openness of the CGF architectures for all the scientific and economic reasons cited above. Clearly, there are trade-off studies that will determine how much time and money should be spent to improve the openness and flexibility of CGF architectures, and that is one of the important reasons for these topics to be included in studies like this. However, it is also the opinion of this expert working group that the requirements for relatively open architectures are almost always underestimated in the military applications where there are serious needs to quickly improve the performance of existing systems with the newest capabilities. It is also our opinion that even preliminary results have shown the benefits for military systems of reasonably open architectures.

Because architecture is an integration concept, a way to provide a common semantic framework for a collection of models, or to put back together components that have been developed separately, our Working Group discussed important issues with the other Technical Working Groups, to identify those that are primarily architectural issues or that would affect or be affected by any proposed architecture.

Our purpose in this Working Group was not to propose a particular architecture, or even an architectural style, but to identify properties that any architecture should have, and to collect context conditions that any architecture should accommodate. No single architectural style suffices for all the different applications of CGFs or all the different uses of simulation. Each simulation developer will of course have a unique mix of requirements and application interests, so the architecture that will be used will depend on that mix. Our purpose in this Working Group was to show how new developments in system architectures can help make these separate systems interoperate more easily.

A simulation system will have many different kinds of components: CGFs, Synthetic Environments, Models of domain entities, forces, tasks, Analysis Tools, Scenario Generation Tools, Visualisation Tools, Mobile Devices, Multimodal Human-Machine Interfaces, C4I systems, Embedded evaluation and monitoring agents, algorithms for continuous, discrete event and Monte Carlo simulations, embedded tutor components, tools for after action review, and many other kinds of automated assistance. In addition to these resources that have immediate utility to the user, there are a number of resources that are necessary components to managing these resources in a flexible way; they are indirectly seen by users in the ease with which the system can be tailored because of the needs of different users, new field requirements or new parts of the system. Among these types of components are domain-specific models that define the configuration for a subset of components, with the detailed specialisations that will allow them to be tailored for a given application.

Even though we can take advantage of good object-oriented approaches and the use of meta-data approaches, a single object or component cannot contain inside itself all of the information required at the whole system level. That is, local consistency of the information within an object, or even each one of a collection of objects, does not guarantee global consistency. There are many attributes of a system that must be analysed (generally using different methods) at both the whole system and the local levels (e.g., risk, performance, validity).

It is our view that the system should perform as much component integration and management as possible, instead of the organisation or simulation owners, because automatic assistance makes it much more likely that the simulation components are consistent with each other and with the assumptions of the simulation study, much more likely that the component interfaces are properly used, and much more likely that automatic reconfiguration and instrumentation tools can be used successfully.

Even if we were all to agree that this list is complete, i.e., it contains all of the important components of a simulation system, we still need flexibility in the architecture, because components and even architectures change with technology. That is, the variety of components, the different kinds of uses of components, and the dynamic nature of technology, together requires a flexible interconnection architecture. It is therefore necessary to define the semantics of the shareable data, that is, the meanings that the users of that data are expected to attach to it, rather than fixing the structure if the systems that will use the data. It is convenient to define the syntax of the data (data formats and structures), but not nearly as important as defining the semantics. If the data syntax is explicit for each data item, then it can be translated or converted appropriately as needed.

3.4 Modelling of CGFs

3.4.1 Introduction

The scope of this section is to identify the technologies required to achieve good rational / cognitive models within a CGF.

One basic assumption is that the physical behaviour of the computer-generated force is fairly well understood whereas the rational and human factors aspects are not. Another assumption is that a good rational / cognitive model of a CGF can be incorporated into any simulation that represents its physical part or into its real-world physical component.

As the architecture of the simulation system plays an important role in the effective use of CGFs, it will be discussed briefly in this section. Next, a generic structure of the rational / cognitive part of the CGF will be described. The technologies that are relevant for the development of each of the modules in this structure are derived. The criticality and maturity of these technologies and the likelihood of being developed for commercial purposes are assessed. Combined with an overall analysis of the contribution of CGFs to the various application areas long-term objectives, a ranking of the technological areas that require military funding is derived.

3.4.2 Architecture

The architecture of a simulation system as shown in Figure 1 enables a flexible organisation of the elements of the simulation, based on the requirements of the area where it will be applied.

The existence of a common “language” allows heterogeneous elements to interact. Furthermore, the same element can be implemented in different ways without impacting on the rest of the simulation. In Figure 1, this common language is referred to as “Interoperability Protocol”.

The interoperability protocol consists of three layers:

(1) The communication layer, which provides the mechanism for the physical transport of messages between the components of the simulation system.

(2) The “grammar” layer, which provides the words and rules for building the messages.

(3) The “semantics” layer, which contains the “dictionary” to attribute meaning to and extract meaning from the messages.

C3I systems, either in an operational or a training mode, are integrated into the simulation system. For training or analysis, a duplication of an existing C3I system or a prototype of a new C3I system can be inserted into the simulation in order to avoid disruption to the real-world operational C3I system.

In analogy to the C3I system, interaction with the environment can take place with a synthetic or a real-world representation. The specific characteristics of the synthetic environment are addressed in section 4.2.

The particular part of the architecture dealing with the rational / cognitive model of CGFs and their interaction will be described in the following paragraphs. The part of the architecture dealing with CGFs and their interaction to humans involves different techniques and will be addressed in section 4.6.

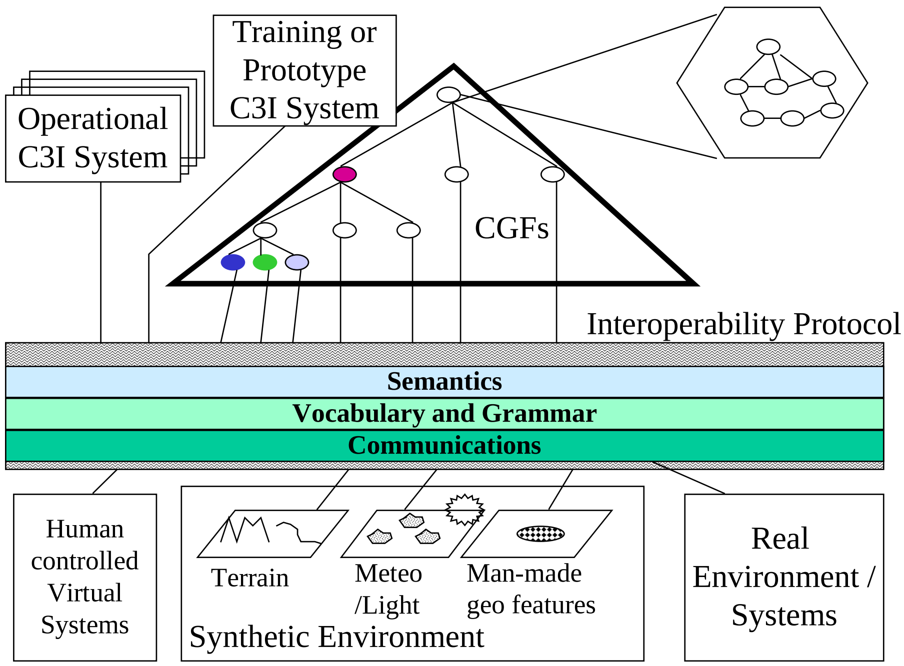

Figure 1: A potential Simulation System Architecture

3.4.3 CGF modules

As shown in Figure 1, the organisation of the CGFs should reflect the structure of the organisation they represent. In case of a military organisation, this generally implies a strictly hierarchical structure. Within a military staff, however, this strict hierarchy does not necessarily apply and a collaborative group decision-making structure needs to be reflected. Hence a CGF representing a specific level of command would be broken down into a number of CGFs representing its respective staff elements. To communicate to each other, the CGFs would use the interoperability protocol discussed in the previous section.

Considering the ability to represent all elements of the civil / military organisation, it is suggested that a sufficiently detailed model to meet the various application areas’ requirements could be a solution to simulating at various levels of information aggregation. Indeed information would be processed through CGFs down to the level of detail of the synthetic environment and would be reported upwards through CGFs to the required level of information presentation.

In order to derive basic technologies to develop good CGFs, the internal structure of a CGF was developed, as illustrated in Figure 2. This proposed structure is derived from a model of the decision making process. Alternative structures could be defined based on a different model. Each of the modules corresponding to a step in the decision making process can be characterised by a set of functions. It can be expected that alternative structures would also include these basic functions.

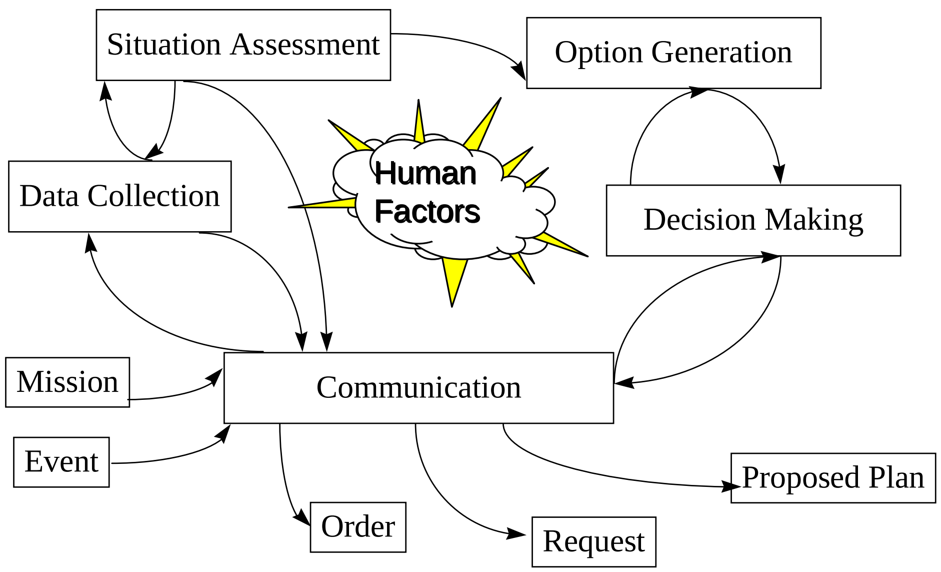

Figure 2: Modules of the CGF rational / cognitive model

The role of each of the modules can be described as follows:

(1) the data collection module is responsible for gathering the detailed data elements as instructed by the situation assessment module;

(2) the situation assessment module defines the detailed data requirements that need to be collected, interprets the mission received by the CGF, updates the current assessment of the situation and defines and monitors critical and meaningful events;

(3) the option generation module develops courses of action based on the triggering event, mission statement and current situation assessment;

(4) the decision-making module evaluates the various courses of action and ranks them according to a set of pre-determined and derived criteria. It will also support the negotiation process between CGFs or human decision makers that may be required to develop a solution for the larger context in which the CGFs decision is included;

(5) the communication module supports the exchange of data between the CGF and all other elements of the simulation system. It transforms data into the appropriate format for local and external interpretation.

The sequence of decision-making steps can be either course of action or goal driven. Some of the modules e.g. situation assessment, may operate in parallel with others while others e.g. option generation need to be triggered specifically. Human factors like stress, fear, fatigue etc. have their influence on all of the decision-making steps. They are, however, considered to fall outside the scope of this section.

Each of the modules are defined as consisting of the following functions:

Module	Function	Description
Data Collection	Get data request	Receive detailed data specification
	Find the data	Query sources Define sources
	Prepare the data	Format retrieved data
	Provide data reference	Report on data source
Situation Assessment	Produce data requests	Specify detailed data requirement
	Interpret and fuse data	Merge and attribute meaning to data
	Monitor critical events	Define critical and meaningful event criteria. Monitor events and assess impact.
	Maintain updated situation	Adapt perception of current situation and verify consistency.
Option Generation	Generate possible courses of action	Taking into account mission, environment, own and other forces, develop feasible courses of action (including empty set)
Decision Making	Rank options	Derive variable criteria. Combine pre-determined and derived criteria. Analyse courses of action.
	Goals decision making approach	Derive intermediate goals.
	Negotiate	Re-define constraints and range of acceptable solutions. Monitor and enforce convergence.
Communication	Interface	With external elements and CGF
	Report	To other CGFs and external elements

Table 2: Functions of the modules of the CGF rational / cognitive model

Module	Function	Technology	Criticality
Data Collection	Get data request	Current database and browsing technologies	H
	Find the data	Data mining (e.g. Selection and discrimination techniques)	H
		Knowledge discovery	L
		Pattern recognition	L
		Knowledge based systems	L
	Prepare the data	Current database and browsing technologies	H
	Provide data reference	Current database and browsing technologies	H
Situation Assessment	Produce data requests	Knowledge discovery	H
		Translation techniques	H
		Rule-based systems	H
	Interpret and fuse data	Task and domain specific data fusion algorithms	H
		Pattern recognition	H
		Neural networks	M
		Image recognition	M
		Natural language processing	H
	Monitor critical events	Flexible object schema for situation description	H
	Maintain updated situation	Blackboards for consistency maintenance	H
		Knowledge based systems	H
Option Generation	Generate possible courses of action	Search algorithms	H
		Simulation	M
		Knowledge based systems	H
		OR	L
		Fuzzy logic	M
Decision Making	Rank options	Simulation	H
		OR	H
		Fuzzy Logic	H
	Goals decision making approach	Planning techniques	H
		Search techniques	H
	Negotiate	Cooperative planning	HH
Communication	Interface	Speech recognition	H
		Image recognition	H
		Gesture recognition	L
	Report	Speech generation	M
		Image generation	M

Table 3: Technology areas relevant to the CGF functions

3.4.4 Basic technologies

Having defined the various constituent functions, the technologies required to develop them can be listed. They are shown in Table 3, along with an appreciation of the criticality of the technologies to the specific function of the CGF module. Criticality is measured as being H(igh), M(medium) or L(ow).

3.5 Human Behaviour Representation

This section is concerned with one single aspect of a CGF - how human decision-making behaviour is represented within a typical CGF. Common understanding, also reflected in the technology working group responsible for examining this technology area, is that Human Behaviour Representation (HBR) is the most difficult issue in devising successful future CGFs with high quality. Technically, one can think of a HBR as a software module that "interacts" with the rest of a CGF and/or with the real world - depending on the application. This interaction must be controlled through the simulation architecture, via HBR objects that access information from real or simulated sensors through real or simulated C4I systems. The nature of this interaction is described in the CGF Modelling and in the Architecture chapters and will only briefly be referred to here.

There are two main approaches to HBR. One is mainly concerned with mimicking human thought processes and is hence here called HBP (Human Behaviour Process). The other is more concerned with a correct representation of the output of a thought process, and is here termed HBO (Human Behaviour Output). The implementation of HBR in software is here referred to as HBM (Human Behaviour Model).

3.6 Human/System Interactions (H/S-I)

In the following are short, mid, and long-term technology solutions for H/S-I systems in CGF described. Short term is defined as currently off the shelf or within three years of being off the shelf. Mid term is defined as from 4 to 10 years out and long term is from 10 to 15 years out.

3.6.1 Results and Timelines for Training and Exercise Problem Areas

Table 4 briefly lays out the results for training and exercise.

Training & Exercise	Short	Medium	Long
Natural interface	• Speech recognition • video conferencing • realistic graphics • gestures for gross manipulation	• Facial expression recognition • natural language processing • reliable gesturing • systems	• Realistic voice synthesis • VR • transparent & natural interface
Time compression	• Expansion to allow students to catch up • compression to save time, may be used to create stress	• Study effects of time compression on learning and operational performance • alternative training and pre-exercise strategies	• Can the manipulation of time simulate wartime stress
Multi-modal	• Output: audio, still & motion video, graphics. • Input: keyboard, mouse/ trackball, touch panels, single utterance speech. • Video conferencing has elements of all	• R&D into adding modes (touch, pressure, tactile). • Improve current modes (360 sound), 3-D. • What is the effect of cultural influences and individual differences on interface effectiveness	• Smell, taste. • Using human sensory system to create stress. • Total immersion systems.

Table 4: The working groups results for training and exercise

Most of these technologies are being developed independently of any military or NATO intervention since they would add value to commercial computer products as well. However, there are two research areas, which should be pursued as a result of this conference:

(1) The effects of time compression and expansion on learning and performance

(2) The effect of cultural differences on interface design and effectiveness.

3.6.2 Results and Timelines for Defence Planning and Operational Analysis Problem Areas

Table 5 provides the timeline for the issues raised by Defence Planning and Operational Analysis.

Force Planning	Short	Medium	Long
Abstract concepts	• Text • maps • flags • simple icons	• Media resources analysis • cultural metrics • probability of particular events	• Set realistic and limited goals • Program should be a series of well defined, short term projects
Drill down	• Lot of data • problem is converting to information • Primarily self selection	• Optimum data base organisation for human use • What information is needed by whom and when do they need it?	• Intelligent agents subject to verification

Table 5: Timeline

The primary research goals here are to establish ways to organise data to that can be used by the right people at the right time. A separate, but equally difficult problem, is to capture abstract concepts (i.e., religious beliefs, tribal loyalty) in some concrete form that can then be represented in a useable form for decision makers and planners.

The need for intelligent agents, which are subject to verification, should also provide a high priority research thrust. Commanders want information they can trust. An intelligent agent must provide that information and also be able to respond to queries about it. The information provided should not be more precise than the truth based on “fog of war”. Therefore there are two research areas recommended by the H/S-I working group to meet the Force Planning needs:

(1) How to represent abstract concepts in operationally meaningful terms.

(2) The development of intelligent agents, which can be subjected to verification.

3.6.3 Results and Timelines for Operations Technologies Problem Areas

Table6 provides the timeline for H/S-I responses to the Operations area.

Operations	Short	Medium	Long
Agents	• Organisers • formats • push technology	• Inference agents (what information do staff need?) • Use simulation to determine what is the necessary and sufficient information for decision making	• Intelligent agents subject to verification
Expressing the complex	• Improved navigational techniques • advanced graphing • visualisation • display of multidimensional data	• Develop a theory for display of multidimensional, complex information	• Automated processing and displaying of complex data. • Task and individual based display
Random insertion of unplanned events	• Stochastic models • unexpected failures	• Critical event detection • automated checklist for critical event detection • automated dissemination of warnings	• Automated detection of critical events • display of critical events

Table6: Timeline

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Computer Generated Forces - Layout and Architecture

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Computer Generated Forces – Integration into the Operational Environment

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ABSTRACT

In closed combat simulation systems CGF modules are most often used to generate orders in given or perceived situations. They can be interpreted as command entities getting information about the battlefield and generating the respective orders, information messages, and requests for the superior command, their neighbors, and the subordinate command entities or units.

In order to facilitate the reuse of CGF-modules as the reuse of observations of the real world of Command and Control, it is highly recommended to use a reference data model. This reference data model should address the information exchange requirements (IER) on the battlefield being used by real decision makers. A matured data model being developed by analyzing the IER of NATO and national military operations on all levels of command by data modeling experts from several NATO countries is the data model of the Army/Allied Tactical Command and Control Information System (ATCCIS), now becoming a NATO STANAG ADatP-32 as the Land C2 Information Exchange Data Model (LC2IEDM). This data model also is used for data management by the NATO Data Administration Group (NDAG) as well as by some national data management agencies.

This paper gives the architecture, shows benefits and limitations, and introduces a way for real reuse of CGF modules within several federations. The High Level Architecture (HLA) builds the technical framework.

1 Introduction

This paper is dealing with the integration of the results of the research domain “computer generated forces” as a special branch of the wider application field of simulation systems. The content is mainly based on three papers: [Krusche and Tolk 1999], [Tolk 1999] and [Tolk 2000a]. These three papers can be seen as a series of ideas having been born within the Data Mediation Think Tank at IABG within the last three years [Krusche et al. 2000]. These ideas result in a general integration framework for applications of military information technology, i.e., command and control systems, simulation systems, or also computer generated forces federates.

Originally, the kernel ideas have been born within the academic world of federated databases [Sheth and Larson 1990]. Federated databases are a more general view on distributed databases, where no common data schema for replication is necessary, but the databases themselves can be heterogeneous, autonomous, and also distributed managed. For a general introduction into this domain, the study of the book [Özsu and Valduriez 1991] as well as the articles by Sheth and Larson are recommended. For interested people who are able to understand German, the German book [Conrad 1997] is also a valuable source.

The challenge to merge distributed, heterogeneous, and autonomous data sources into a common operating picture is also formulated for command and control systems. A first try to use the theory of federated database systems to do so was presented during the Joint Warrior Interoperability Demonstration 1999 (JWID 99) and is documented in [NC3A 1999]. Germany and the UK are following this path to gain long term interoperability for their national systems. Crucial for the benefit

Paper presented at the RTO SAS Lecture Series on “Simulation of and for Military Decision Making”, held in Rome, Italy, 15-16 October 2001; Stockholm, Sweden, 18-19 October 2001; Virginia, USA, 23-25 October 2001; The Hague, The Netherlands, 10-11 December 2002, and published in RTO-EN-017.

of these efforts is a common data management with respective IT support. For this purpose, NATO has established the NATO Data Administration Group (NDAG). However, there are other alternatives that are not pushing forward to such a strong paradigm shift like the federated solution approach.

Anyhow, for the simulation community, the idea of federations is not very new. They are dealing with distributed, heterogeneous, and autonomous data sources since the days of SIMNET, followed by the distributed interactive simulation (DIS), advanced level simulation protocol (ALSP), and finally the high level architecture (HLA). However, the idea of a standardized common information exchange model is also a new challenge to them. The logical idea therefore is to merge the ideas of the high level architecture and federated databases to a new common approach, leading on the long term to a new generation of warfighter supporting IT systems comprising the necessary functionality (command and control, consultation, intelligence, surveillance, reconnaissance, simulation for training, simulation for decision support, etc.) in modules plugged into a common integration framework like described, e.g., in [Tolk 2000b].

The paper tried to catch the main ideas of the referred papers in a comprehensive manner. For more details, please evaluate the original papers directly.

2 Databases, Data Management and Command and Control Solutions

Each organization in the domain of defense depends on access to information in order to perform its mission. It must create and maintain certain information that is essential to its assigned tasks. Some of this information is private, of no interest to any other organization. Most organizations, however, produce information that must be shared with others. This information must be made available, in a controlled manner, to any authorized user who needs access to it.

At present, almost every defense information infrastructure exists as a collection of heterogeneous, non-integrated systems. Each organization builds systems to meet its own information requirements, with little concern for satisfying the requirements of others, or of considering in advance the need for information exchange. The information sharing that currently occurs is performed through many, point-to-point interfaces, typically through a defined message or file-transfer format. Some message formats are clearly defined (e.g. ADatP-3 and Data Link messages). For the most part, however, information exchange is based on ad hoc interfaces. The result is an extremely rigid information infrastructure that costs months and millions to be changed or extended, and, which cannot cope with the increasing demand for widely integrated data sharing between multiple mission-related applications and systems.

2.1 Federated Databases for Distributed, Heterogeneous, and Autonomous Data

Before starting with the military application of integrating several components comprising the needed functionality into a general integration framework, the ideas of building federated databases for distributed, heterogeneous, and autonomous data will be introduced. Therefore, we will follow the way of [Conrad 1997] starting with homogeneous local databases and coming via the distributed homogeneous databases to federated solutions. The same initial stage is also chosen in [Tolk 2001].

The ANSI/X3/SPARC of the American National Standards Institute standardized the three level schema for homogeneous local databases. The lowest level is the physical or internal schema. This is the system dependent implementation of the system independent conceptual schema, which is the second schema. The conceptual model comprises the complete data that can be stored within the database. As every application may have its own view of the data in doesn't need to know about all the other details (for reasons of security as well as integrity of the data, juristic questions, etc.), there is an external schema for every application comprising just the data subset with the respective rights to read, write, and add new data needed for the functionality provided by the application. Therefore, internal, conceptual, and external schemata are the three standardized levels.

When distributing such a homogeneous database, an additional level is needed. Again, [Özsu and Valduriez 1991] define one external schemata for every application, however, the conceptual data scheme becomes now the common schema for replication, i.e., this is the common data model for all participants/databases. All databases are joining the same common data model. Anyhow, it may not be necessary to store every table and detail in every local database. Therefore, local conceptual schemata are introduced that have to be implemented using the respective local internal schemata. Therefore, local internal, local conceptual, conceptual, and external schemata are the four levels for distributed homogeneous databases. This is the right technique for a homogeneous system, e.g., a network of command and control systems of the same kind within a headquarter. It is also the mid-term way followed in the operational environment. The warfighter IT systems of the next generation should be able to share data using data replication instead of just sharing and interchanging messages. Especially in the US the efforts to use a common data model – at least for the services – is a favored idea.

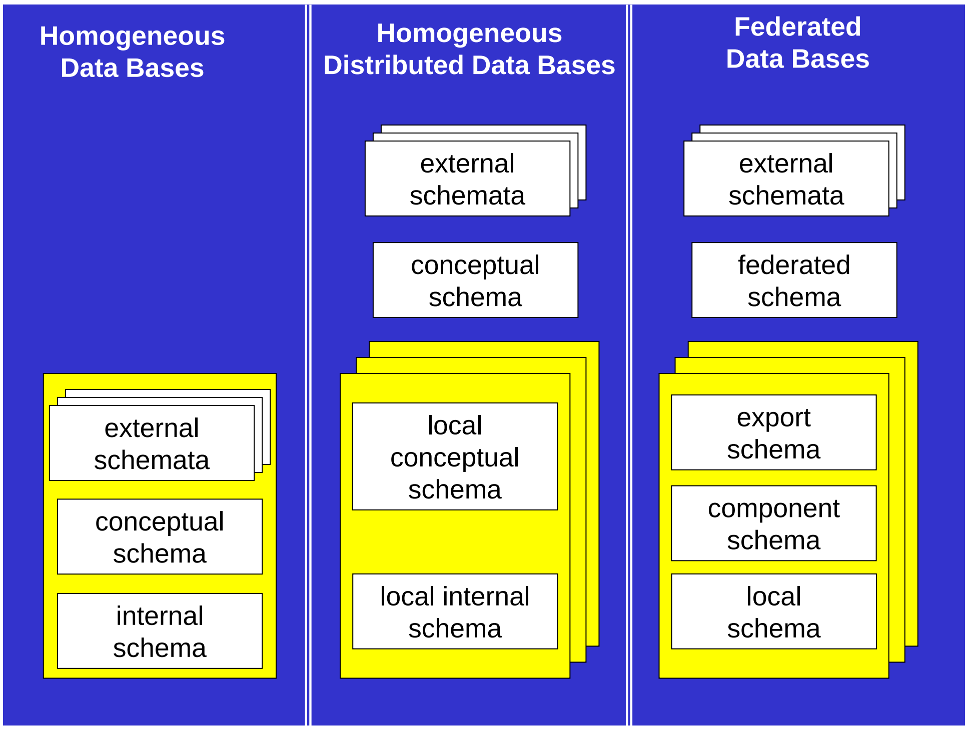

Figure 1: Schemata Levels in Databases

However, when having to deal with the integration of legacy solutions, new approaches are needed. In joint and combined operations, the availability of a common IT environment will be a pure wish for a long time. In addition, the different partners will prefer to work with the system they know the best: their own. The approach using a common conceptual data model cannot be used, as every legacy systems already has one of their own. Within such an environment, integration methods are needed that are able to cope with existing autonomous, heterogeneous systems that have to work together – often on an ad-hoc basis. This can be done using the ideas of federated databases, also used in the domain of electronic commerce, e.g. in the area of Collaborative Product Commerce (CPC), see [Krusche and Tolk 2000] for some details.

Therefore, Sheth and Larson introduce a new five level architecture in [Sheth and Larson 1990]. Every application has again its own data view, the external schema. They are based, however, on a so called federated schema being the common data exchange data model for all participants. Different from the conceptual schema of distributed homogeneous databases, the federated schema only comprises the shared data elements and doesn't deal with all details of the local autonomous databases.[1] The local databases are contributing to this federated schema their part by export schemata comprising the data

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[1] This enables the evolutionary growing of the common data exchange model based on the actual information exchange request being formulated between the global applications and the local databases. In the moment, a new data piece is needed in a global application, it becomes part of the federated schema. However, the local databases don'' have to be changed as long as the piece of data is already comprised in one of them.

to be shared by the local database with other databases. Each export schema is part of a local component schema, which is a common presentation of the data elements being comprised in the local, system dependent schema. Therefore, the five levels are external, federated, export, component, and local schemata.

The influence of this technique on continuously interoperable solutions for the warfighter is described also in [Tolk and Kunde 2000] and [Krusche and Tolk 2000]. Many application examples can also be found in [Krusche et al. 2000].

2.2 Standard Data Elements

Fundamental to any systems' interoperability are standard data elements, i.e. those data elements that have a concise, unambiguous, and agreed, syntactic and semantic definition. These data elements must be considered as an operational asset, which, like other organizational assets, must be managed effectively and organized to facilitate access by those who require it, in accordance with the need-to-know principle and agreed security regulations and constraints. This is also a central idea within the concept of the shared data environment (SHADE), see [DISA 1996].

The definition of standard data elements required for information exchange, the coordination and control of their implementation and use within systems are central objectives of an overall data management organization, which will be described in more detail in the next section.

An important outcome of the data management is a common (shared) data model, which defines how each standardized element of information is represented, and, which also provides a common guideline for system developers of future systems.

In order to meet the migration requirements of existing system components and systems, standard data elements and its common representation must be accompanied by standard mapping rules, which allow the as-is meta data from a system to be defined in terms of the common standard data model when the data meaning is established.

Fundamental to the realization of the migration requirements are standard data access mechanisms, which implement standard data and mappings and allow users to access and interchange as-is data without knowing information about the common, standard data representation. The access architecture contains the data mediation capabilities required to provide the user with this transparency.

The main aspects to achieve systems interoperability,

- a data management organization,
- a common shared data model, together with standard mapping rules, and,
- a common data mediation mechanism for migrating existing system components and systems,

reflect the central conceptual features of the SHADE.

The approach towards systems interoperability, described in this paper, stresses the fundamental meaning of an overall data management, promotes the ATCCIS Generic Hub [NATO 2000] as an appropriate basis for the common, shared data model, and, introduces a data mediation framework as a common mechanism to interconnect heterogeneous system components and systems, thereby extending the SHADE approach.

2.3 Data Management

The overall objective to be reached by introducing a data management is, to coordinate and to control the numerous system projects technically and organizationally, in order to improve the integrity, quality, security and availability of standard data elements. Due to this objective, the following central tasks of the data management organization are proposed:

- Definition of standard data elements across system boundaries,
- Evolutionary development of a common shared data model as a reference representation for standard data elements,
- Representation of standard data elements through a common shared data model,
- Definition of rules and methods for
  - access, modification and distribution of standard data elements,
  - introduction of new information exchange requirements,
- Coordination and Control of system projects using the standard data elements in order to assure their consistent use and interpretation within different applications and systems.

Thus, data management is planning, organizing and managing of data by defining and using rules, methods, tools and respective resources to identify, clarify, define and standardize the meaning of data as of their relations. This results in validated standard data elements and relations, which are going to be represented and distributed as a common shared data model.

An appropriate reference representation of standard data elements, as an important product and outcome of the data management activities directly enables the standardization results to be implemented in future system components (i.e. database systems, applications), and, provides a common basis to interconnect existing systems through a data mediation framework. The following figure depicts the practical use of Data Management for the configuration of Data Mediation Layers as described in more detail in [Krusche and Tolk 2000].

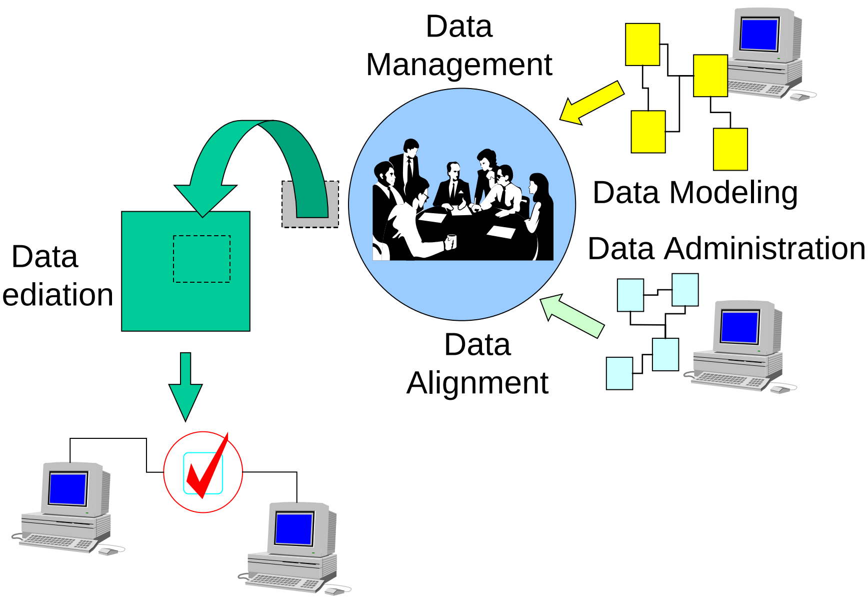

Figure 2: Using Data Management Results for Integration

A common (shared) data model must fulfill the following two main requirements:

- It must capture the information requirements of a wide range of battlefield functional areas. A common shared data model is best characterized as a "to-be" model of the required battlefield information rather than a model that is constructed with direct reference to existing current needs for information exchange.

- For flexible integration of future information (exchange) requirements, the data model must be constructed in a way that future information elements simply extend the model while its existing structure remains unchanged.

The ATCCIS data model [NATO 2000] meets both requirements quite well, as it has been designed to meet exactly these requirements by data modeling experts of almost all nations in NATO during the last 10 years.[2] It will be explained in more detail in the next section.

2.4 Data Modeling with ATCCIS/LC2IEDM

In 1978, NATO's Long-Term Defense Plan (LTDP) Task Force on Command and Control (C2) recommended that an analysis be undertaken to determine if the future tactical Automatic Data Processing (ADP) requirements of the Nations, including that of interoperability, could be obtained at a significantly reduced cost when compared with the approach that has been adopted in the past. In early 1980 the then Deputy Supreme Allied Commander Europe initiated a study to investigate the possibilities of implementing the Task Force's recommendations. This was the birthday of the ATCCIS Permanent Working Group (APWG) that is dealing with the challenge of the future C4I systems of NATO. Today, the ATCCIS ideas have matured sufficiently and, thus, ATCCIS is on its way to become a NATO Standardization Agreement (STANAG).

ATCCIS is much more than just another data model. It is designed to be an overall concept for the future C4I systems of the participating nations.

However , one of the most important topics of ATCCIS is that each nation still can build independent systems with their own "view of the world" and respective applications, business rules, implementation details, etc. Thus, ATCCIS is not designed to be a "buy or be out" product, but is defining a common kernel to facilitate common understanding of shared information and, therefore, facilitating facing the general challenge to reach interoperability.

The Army/Allied Tactical Command and Control Information System (ATCCIS) comprises

- the ATCCIS data model (including a standardized common generic hub and subfunctional areas of national concern),
- the ATCCIS system architecture (with a kernel of common access points to the logical ATCCIS data model on the one side, and access points to standard communication protocols like TCP/IP on the other),
- the ATCCIS Information Resource Dictionary System (AIRDS) with references about information and information structure and context for each data element, and
- the ATCCIS Replication Mechanism (ARM) allowing internal communication by user driven and specified database replication between two ATCCIS compliant systems.

In the context of this paper, we will focus on the data model. When talking about the ATCCIS data model one has to distinguish between the Generic Hub (GH), which is a kernel of data elements common to all application areas of ATCCIS, and the so called Subfunctional Areas (SFA), which extends the Generic Hub to a degree of a special application, e.g., fire support, personnel, etc.

The ATCCIS Generic Hub data model is intended to represent the core of the data identified for exchange across multiple subfunctional areas and multiple views of the requirements. Toward that

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[2] Only recently, the work of the Army Tactical Command and Control Information Systems (ATCCIS) Permanent Working Group become considered as a new NATO standard for information exchange. The new name is Land Command and Control Information Exchange Data Model (LC2IEDM). However, it should be stressed that the references ARMY as well as LAND in the data model names are misleading in some way. ATCCIS is not an army data model, but an ontology to structure knowledge of the military domain in a consequent and coherent way. In Germany, the ADatP-3 messages of the Maritime Headquarters and the Destroyers, the Link 11 and Link 16 as well as the OTH Gold messages have been harmonized using the ATCCIS data model, therefore, the model can be seen to be proved to be able to be extended in a controlled manner to comprise information for army, navy, airforce, and joint operations and respective forces.

end, it lays down a common approach to describing the information to be exchanged in a tactical command and control environment. Thus, the approach is generic, i.e., it is not limited to a special level of command, force category, etc. It moreover tries to catch the idea of object oriented modeling for data modeling by starting with very basic concepts of data – like object items, object types, actions, facilities, etc. – and allowing the specification of, gradually, more and more details in order to match real instances on the battlefield.

To summarize, the data model needs to describe all objects of interest on the battlefield, e.g., organizations, persons, equipment, facilities, geographic features, weather phenomena, and military control measures such as boundaries using a common and extensible data modeling approach.

The following figure shows the key entities of the Generic Hub data model. The five key entities can be described as follows:

- An OBJECT-ITEM is an individually identified object that has military significance.
- An OBJECT-TYPE is an individually identified class of objects that has military significance.
- A CAPABILITY is the potential ability to do work, perform a function or mission, achieve an objective, or provide a service.
- A LOCATION is a specification of position and geometry with respect to a specified frame of reference.
- An ACTION is an activity, or the occurrence of an activity, that may utilize resources and may be focused against an objective

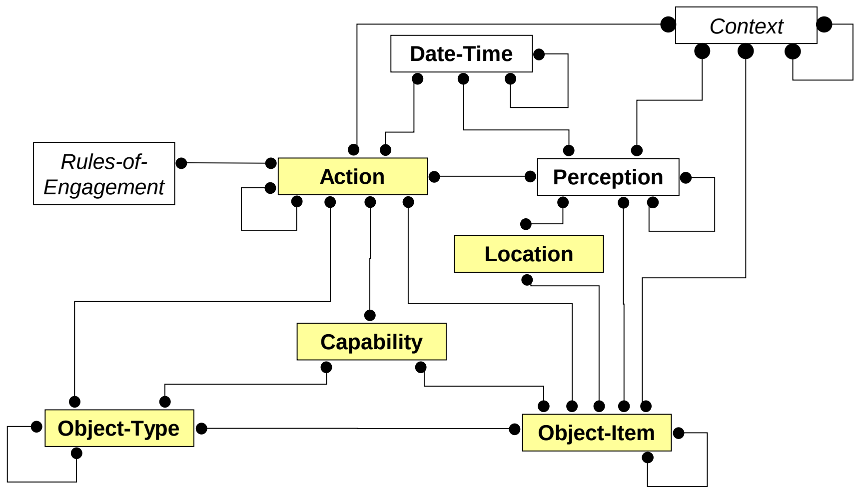

Figure 3: Key Entities on the Hierarchy Level of the Generic Hub

For each key entity, several levels of subtree hierarchies can be derived – and have been standardized to a certain degree – by introducing new categories of OBJECT-ITEMS, OBJECT-TYPES, CAPABILITIES, ACTIONS and LOCATIONS.

The following figure illustrates this for the first two levels of the OBJECT-TYPE and OBJECT-ITEM subtree hierarchies. Each object (be it type or item) can represent an ORGANIZATION, a PERSON, a sort of MATERIEL, a sort of FACILITY, or a sort of a FEATURE as immediate subtypes.

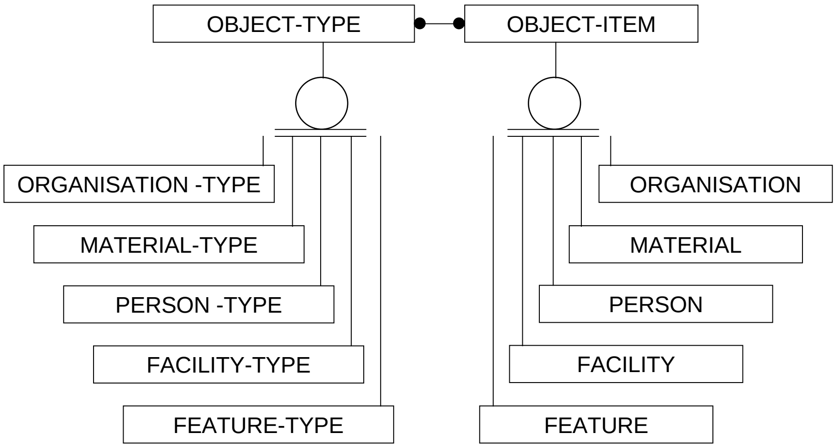

Figure 4: Subtree Hierarchy of OBJECT-TYPE and OBJECT-ITEM

The definitions are as follows:

- An ORGANIZATION is an administrative or functional structure.
- A Sort of MATERIAL is necessary to equip, maintain, and support military activities without distinction as to its application for administrative or combat purposes.
- A PERSON is a human being to whom military significance is attached. This includes not only soldiers, but civilians, refugees, and – if necessary – terrorists, paramilitary forces, or deputies of organizations with significance to the ongoing operations (e.g. Red Cross, NGO, etc.)
- A FACILITY is built, installed, or established to serve some particular purpose and is identified by the service it provides rather than by its content.
- A FEATURE encompasses meteorological, geographic, and control features that are associated with a location to which military significance is attached.

All definitions refer to the standard described in [NATO 2000] where additional examples are given. The data elements belonging to the generic hub of the ATCCIS data model are going to become an agreed standard between the participating nations. In addition to the elements described above they comprise data elements to model establishments, holdings, date and time, perceptions, contexts, etc. It is already possible to model rules of engagement, assessments, tasks, etc.

In order to be able to meet all information exchange requests not only today, but also in the future, it was necessary to establish a procedure to integrate new knowledge to be exchanged seamless into the existing information model. Thus, the subfunctional areas (SFA) were introduced catching special requirements using the same modeling scheme like the generic hub but being of national concern. However, the data elements of the respective SFA can be standardized also, if needed and wished. There is already work going on in the fields of intelligence, fire support, communications and electronics, logistics, and personnel. In a recent study in Germany it has been shown that an SFA for Military Operations Research and Modeling and Simulation can be derived from the analyses of respective data models of simulation systems also.

Every data element within an SFA being shared with another SFA has to become an element of the generic hub that comprises all shared elements. Every data element being special to an SFA is only shared within this area and is of national concern.

2.5 ATCCIS as a Shared Data Model for Command and Control and Simulation Systems

It should be clear by now that every information exchange requirement that exists between two headquarters – or a headquarter and a unit – can be modeled within the ATCCIS approach. Well known information exchange data will be found in the standardized Generic Hub of the ATCCIS data model. New pieces of information being explicitly new within a new operation or scenario can be modeled in a respective SFA for such classes of operations.

As mentioned before, in recent studies in Germany it has been shown that

- ATCCIS can be used as a shared data model for information exchange between C4I systems (including consultation systems) and
- ATCCIS can be used as a shared data model for information exchange between operation research and simulation systems also.

Therefore, ATCCIS can be used as a general shared data model for information exchange between all these systems as well. It will be shown in the next section that CGF modules – when being used as command agents – are simulated data twins of military headquarters. Thus, everything they want to know or want to communicate they can exchange with their counterparts using the language of ATCCIS. It is then part of the simulation – or another CGF module/federate – to retranslate ATCCIS into its own internal data presentation.

3 CGF Modules

Up to now, we have only talked about shared data models and communications between headquarters and units. It is now time to make the connection to the computer generated forces.

Following the definition of the NATO Long-Term Scientific Study LTSS/48, computer generated forces are “A generic term used to refer to computer representations of entities in simulations which attempts to model human behavior sufficiently so that the forces will take some actions automatically (without requiring man-in-the-loop interaction)” [NATO 1999b].

In this definition, forces are “Military entities as they are used in conflicts, peace support operations, and other engagements (operations) like disaster relief, and other civilian entities and individuals as they are engaged in actions represented in the simulation system” [NATO 1999b].

In general, CGF can be seen as intelligent simulated elements behaving in a simulated environment like a human or group of humans would do within the counterpart in the real world.

In this paper, the focus of CGF is military headquarters, i.e. simulated entities that have to generate orders for the effective entities within a simulation (combat units, combat support units, etc.). When doing so, they have to take several constraints into account: the objective and orders of their superior commands, their own resources, the perceived intention of the enemy, the situation of the neighbors, etc. Thus, we are focusing not so much on a model for a single person. We are dealing with a model for a group of persons, i.e., a staff making decisions.

3.1 A Modular Concept for Command and Control in Simulation Models

A modular concept for command and control in simulation models has been presented to the NATO SAS Panel on this topic in January 1999 in Paris, France [NATO 1999a]. It comprises effective entities, command and control modules, reconnaissance modules and communications modules.

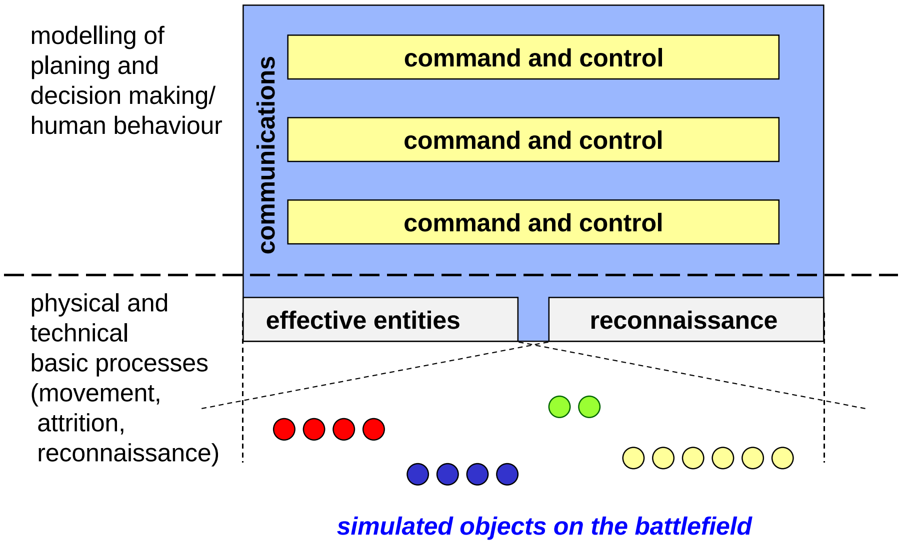

Figure 5: Modules for Command and Control Modeling

- The effective entities are used to model the physical and technical basic processes, i.e. movement, attrition, etc. They just receive orders that tell them what to do. They act and react as predefined taking into account their own actual perception of the situation. On the chosen level of abstraction, the entities receive orders and change their own as other status parameters respectively. This is the part of the simulation model application developers focused on until recently.
- Using a command and control module enables the application developer to model a command post or another element on the battlefield, which receives and generates orders, demands and situation reports. This module is the main topic with this section.
- The reconnaissance module gets orders and generates situation reports. To be able to do so, it groups atomic entities that are able to observe their environment with or without sensors in order to discover the status parameters of the other entities and inform respective command and control modules by predefined reports.
- Every order, demand and situation report must be transported by - i.e. passed via - an incarnation of the module communications. This module receives orders, demands and situation reports and deliver them, perhaps modified due to incoming information operations like jamming or introducing false reports or viruses changing the content of the data packages etc., from the source to the target.

The main driver for this architecture was the urgent need to add command and control functionality to existing or legacy simulation systems without having to rebuild everything. In addition, the new CGF modules were expected to be open and flexible enough to be used within various simulation systems. Therefore, the idea was born to build a CGF federate to be used within an HLA federation and being responsible for the decision processes on the different command levels.[3]

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[3] With the simulation model FIT, in the meantime at IABG a respective model implementing this ideas have been successfully introduced. The approach of FIT is a topic of its own and his been presented on various symposia already, see, e.g. [Knoll 2000] or the proceedings of the 39. AORS at Ft. Leavenworth, Virginia, October 2000.

3.2 ATCCIS as a Language for CGF Modules

To be able to define such a federate, a general approach for exchanging information between CGF and other modules was needed. There are three principle types of partners to exchange information with.

- Superior command elements give orders and receive requests. In addition, situation reports are exchanged.
- With neighbors, situation reports are exchanged to be aware of potential dangers.
- Subordinate commands and/or units get orders and give requests. Again, situation reports are exchanged.

Thus, the information exchange comprises orders, requests and situation reports. For these information exchange requirements the data model ATCCIS can serve as a general shared data model. As it was designed to catch exact such information, it can be used to specify the content of the information to be exchanged between the simulated entities also.

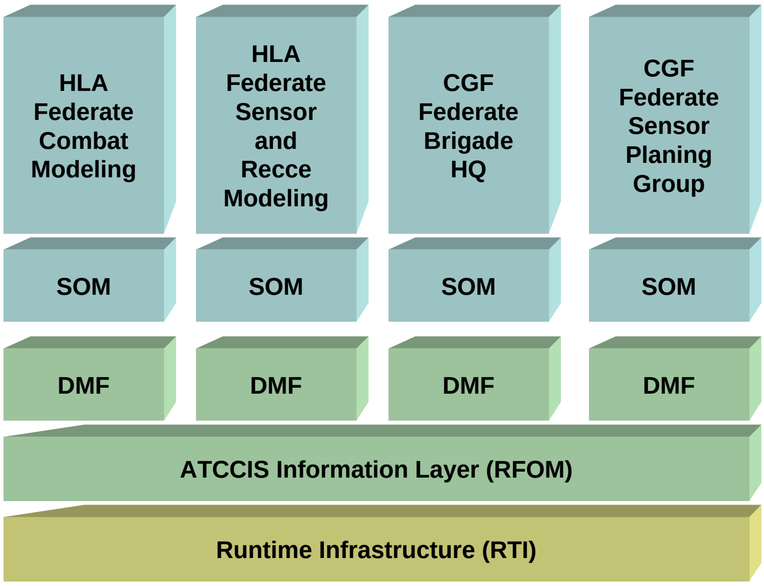

Figure 6: The General Information Integration Framework

The elements of the ATCCIS/LC2IEDM therefore can perfectly well serve as information objects to exchange the necessary data between the application modules of military IT systems.

3.3 Practical Example: The German Communications, Command and Control Model FIT

There are already applicable software implementations of these ideas of modular and configurable command agents. Based on the concepts introduced in this paper, the German C3-Model FIT (*"Führungs- und Informationstechnologie"*) has been designed and implemented by IABG to meet the requirements of the German Army within the domain of command and control and C2 support to

- Evaluate the influence of evolution and progress of C2 information systems (C2IS)
- Support the Planning of C2 for specific operations
- Model the use of existing C2 structures in operations for full-scale rehearsal, improvements, and training.

The application also can bridge the gap between the warfighter and the procurement office, developers and implementers in industry, planers and operators. It is therefore planned by the German Army Office (*"Heeresamt"*) to distribute the model to potential users within the Department of Defense, the Army Office, and Schools of the Army.

The following figure depicts the model architecture reflecting the original ideas quite well. The embedding simulation system HORUS is also a system developed by IABG. Both parts can be coupled either traditionally or using HLA. However, both parts are not yet able to "talk LC2IEDM", but there are already efforts going on to change this.

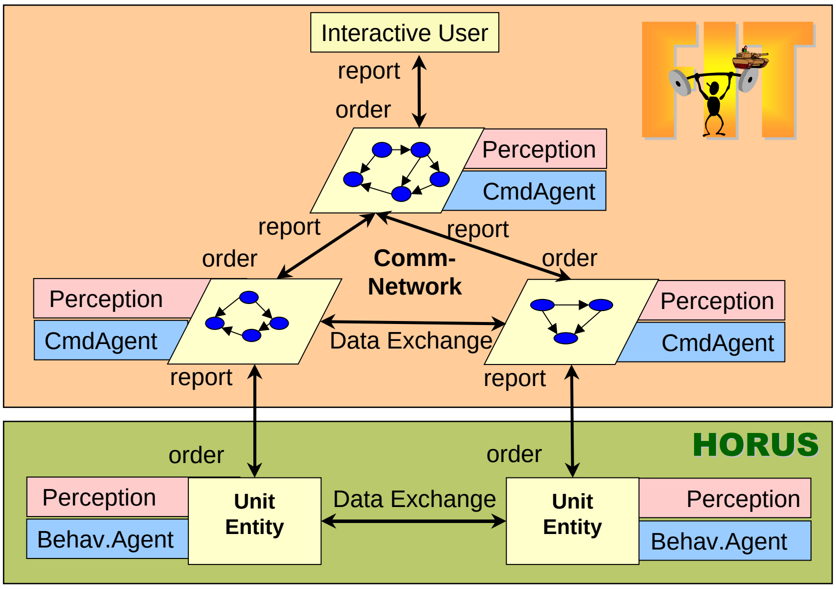

Figure 7: The FIT Model Architecture

Within the domain "Training and Exercises" the FIT model is planned to be used as a computer assisted exercise (CAX) tool for command and control support troops. Within the domain of Support to Operations, FIT can be used for the implementation of realistic command agents to be used for adequate generation of orders for the simulated forces in closed combat simulation systems to be used for alternative courses of action analyses.

A better description can be found in [Eberhard et al. 2001].

4 Information Resource Dictionary Systems

The next idea to be introduced is to use information resource dictionary system (IRDS) techniques to enable the configurable data model translation needed for the already introduced data mediation functionality. More information can be found in [Krusche and Tolk 1999], [Tolk 1999] and [Tolk 2000a] as well as in [Krusche et al. 2000].

The main ideas of an IRDS are defined in the ISO IRDS standard [ISO 1990]. The main purpose of an IRDS is to support data administration and data management. A NATO application example can be found in [NDAG 1999]:

Data administration is an information intensive process involving a wide range of participants. The information required is generated, managed, and used by a large number of participants. Every authority delivering an application to participate in multiple federations – consuming and delivering data from and for the federation – has to be involved in this process of data management. Therefore, it has to be a main purpose of the data administration activities to achieve an effective collaboration between all these participants in the process of establishing a common data standardization lifecycle to gain and preserve a common understanding of the shared data.

An IRDS can be defined as a software system comprising and managing the information resource dictionary in which the information of all participating applications will be recorded. It has been shown, how this idea can be extended in the way, that the IRDS can also be used to support the federate integration process of the high level architecture by making the efforts of the data standardization community usable for the federation builders. The purpose and tasks of data management already have been described earlier.

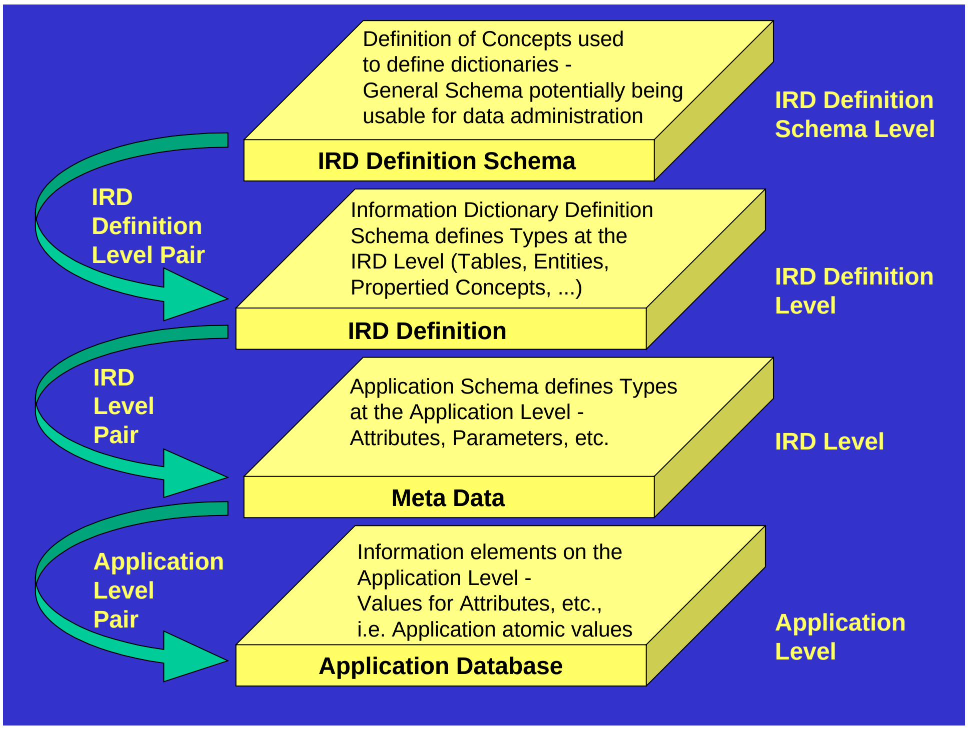

Figure 8: Levels of Information in IRDS

The IRDS framework defines four levels of information. Each level in the framework has a sub-level that consists of the definition of the information contained in its respective sub-levels. Therefore, the use of the ISO IRDS framework allows a gradual introduction of concepts and methodologies from the most abstract form down to most concrete and tangible application and implementation requirements. Thus, the different methodologies of HLA-OMT data modeling, relational data modeling using ,e.g., IDEF1X, and object oriented modeling using UML are nothing more or less than different concepts within the IRDS on the respective level.

The idea of level pairs should be described in a little bit more detail. Each level pair consists of a type concept defined in the upper level and an instance concepts being contained in the lower level. Table 1 illustrates the four levels defined by [ISO 1990] and shows the possible level pairs.

***Table 1**: Levels and Concepts of the IRDS Framework*

Level	Illustrative Level Concept
IRD Definition Schema Level	IRD Schema. IRD Table, IRD Column, IRD Object, IRD Template
IRD Definition Level *(Methodology)*	Entity Type, Attribute, Relationship, Table, Column, Constraint, Object, Parameter
IRD Level *(Model)*	Person-Name, Person-Sex, Person-Profession
Application Level *(Data)*	Lara Croft, definitely female, Game Adventurer

In [Tolk 2000a] has been shown that in such an IRDS entity relationship model meta data such as entities, attributes, relationships ends, cardinalities of relationships can be stored as well as the classical and extended concepts of object oriented modeling techniques like classes, types, constructors, inheritance, specifications etc. In the same way, the meta data of HLA-OMT can be contained.[4] On the highest level, the schemas are the objects about what the information has to be interchanged or shared. Thus, on the highest level the concepts are identical. The "technical gap" between the different methodologies vanishes, they can be mediated into each other.

Furthermore, the respective level pairs can be translated into HLA-OMT tables and therefore can be transmitted via the RTI to be interpreted respectively by the receiving federate. Thus, the HLA-OMT not only comprises elements from the application level (as have been the original purpose of the design), but meta as well.

Following the idea of [Tolk 2000a], it is possible to populate the IRDS with different data and or objects models and mediate them into each other using respective mediation services directly deriving from the standardization efforts.

Thus, it is possible to describe a data model within the IRDS, harmonize it with the agreed shared data model to find the matching standardized data elements (SDE) and use the HLA-OMT to describe the respective SDE syntactically. The other model has to be treated in the same way: As having been harmonized with SDEs also, the incoming SDE can be mediated into the object model of the application also. Therefore, both applications can talk to each other using the HLA-OMT without having to agree to a common model or even a common methodology.

All shared information can be translated into the view of the respective application, as not only the application level information is available, but also the meta-information describing its structure. Furthermore, this methodology is open to future standards and extensions also. E.g., it is no problem to define CORBA IRD definitions (which are nearly identical with respective object hierarchies), XML IRD definitions or other forms to structure information. The following figure depicts these ideas.

In other words: To achieve real interoperability and reusability of software components, e.g., simulation systems as federates within several federation, without the need to re-implement the interface for every single federation, it is necessary to gain a common understanding of the shared information first. Thus, the definition of standardized data elements is necessary. The efforts in standardizing the data can be used to populate a respective IRDS. The content of this IRDS can be used to map federate data elements to SDEs. These SDEs can be described in form of the HLA-OMT, no matter in which methodology the respective data or object model has been developed.

Following this way spares time, effort and – therefore – money and guaranties reusability and interoperability of the managed applications of the domain, be it simulation systems or command and control systems or computer generated forces federates.

It should be stated clearly, that actual works trying to define, e.g., a consistent object model for the army to be used within future simulation systems, or works comparing the information content of command and control databases with the information need of simulation systems are very valuable for the effort described in this paper. The better and more complete the models the easier will it be to find good, reliable, and stable reference models that can serve as the needed common shared data models. And, as long as the efficiency of respective algorithms doesn’t require another form of a data representation, these models can really serve as common data models for a specific type of domain applications.

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4 It was one of the great concerns that the Object Model Template (OMT) of the High Level Architecture (HLA) may not be mighty enough to cope with relational models or object oriented systems. In [Tolk 2000a] it has been shown that these methodologies can be transferred into each other.

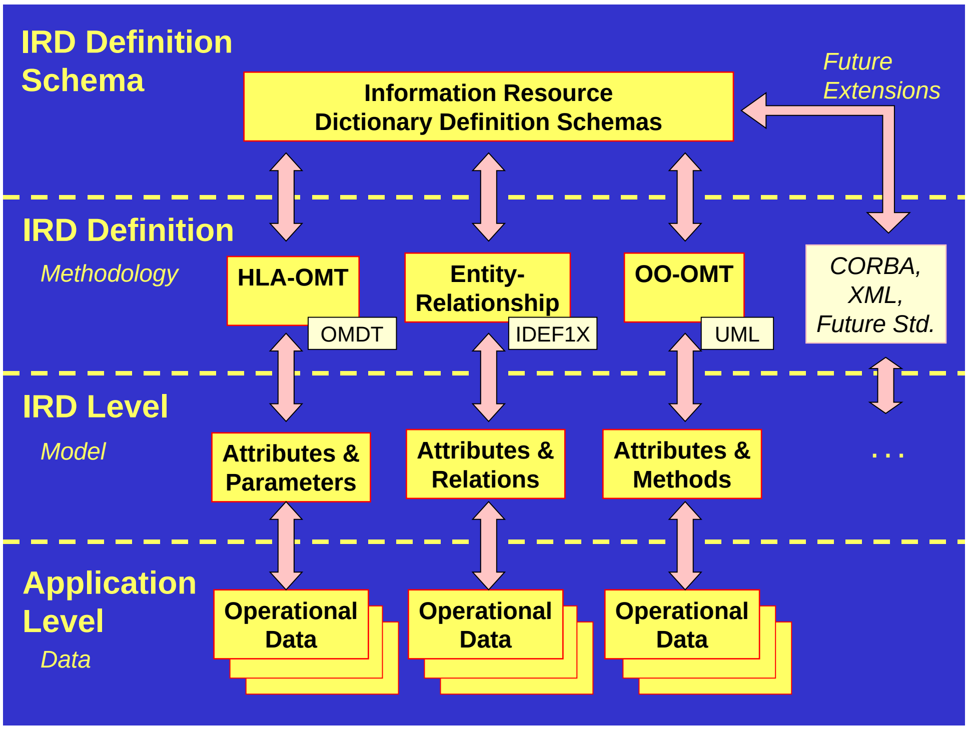

Figure 9: Shared Information Translation supported by an IRDS

5 Summary

The paper comprises the main ideas of federated solutions. A common shared data model introducing a common understanding of the interchanged data is a first step into the direction of continuous interoperability of systems. The idea of federated solutions can also be found in [Tolk and Kunde 2000], where the "house slide" for federated solutions has been described the first time.

The Study Group on Interoperability between C4I System and Simulation Systems (SG-C4I) of the Simulation Interoperability Standardization Organization (SISO) developed a framework to cope with this issues [Timian et al. 2000]. The following figure – introduced by Michael R. Hieb and Andreas Tolk for a briefing of the Simulation Interoperability Standardization Organization (SISO) – comprises the fields to by harmonized and coped with to come to shared solutions.

First thing to be done is the alignment of architectures, so that components of both worlds are able to talk to another. The next level comprises common data and object models as well as common tools and common standards. This will lead to reusable components. However, to be able to reach real interoperable shared solutions, the processes have to be aligned also (e.g., using the same tools and methodologies) including procedures to migrate legacy systems to this new common world. Thus, more or less a change in philosophy of looking at C4I and simulation systems may be needed, e.g., when looking at M&S in acquisition, requirement analyses, support to operations, and training. Maybe, on the long term there will be no longer the distinction between both worlds but new systems will comprises functionality of both worlds as federates.

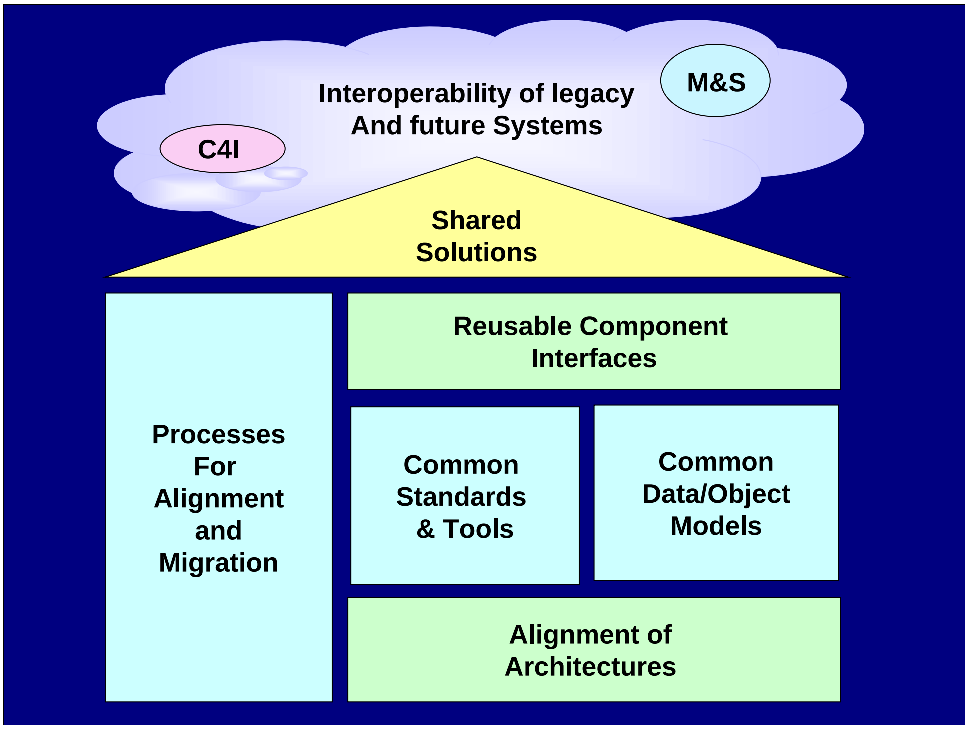

Figure 10: Interoperability Issues of Shared Solutions

Using this techniques it becomes possible to integrate the findings of respective computer generated forces research into the operational environment in the same way that can be used to develop the next generation of warfighter supporting IT systems.

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Computer Generated Forces - Future Needs

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Human Behaviour Representation - Definition

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Abstract

This paper is taken from the Final report of LTSS SAS-017 on Human Behaviour Representation in which A. v. Baeyer and J. Mylle gave this definition of HBR.

1 The importance of "Human Behaviour Representation"

The end of the Cold War has brought new military tasks and types of operations to NATO. These include regional contingency operations, Crisis Management and support of non-NATO missions (UN, PfP, WEU, etc). All these new types of missions have one newly emerging characteristic that implies a better modelling of human behaviour: they need methodologies to describe on various detail levels, how individuals and social entities (e.g. teams, groups) influence the course and outcome of military conflicts. Those emerging technologies will have a great impact on the implementation and on the military use of simulation systems in the future. Therefore, building better simulation systems and decision support tools, which include HBR, is of primary importance.

2 Definitions

2.1 Human behaviour

Human behaviour (B) is a purposive reaction of a human being (P) to an idiosyncratic meaningful situation (S).

Formally expressed: B= f (P,S). In words: the observed variability in behaviour is attributable to differences in the person's characteristics, to differences in the situation and/or to the interplay of both.

- Mathematically spoken: the variation in the measured behaviour can be explained by the variation in P, the variation in S and interaction between P and S (measurement error not taken into account). This definition implies that human behaviour:
- is a change from one state into another state (bodily and/or mentally);
- is always goal-oriented (but not necessary in a one to one relation)
- is a reaction to an external observable stimulus or to an internal covert stimulus,
- has three interrelated components: a cognitive, a psycho-motor and a socio-affective component

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- is an integration of several physiological and mental processes
- is individualised because each individual interprets the objective characteristics of the situation;
- is neither necessary „rationale“ nor the most appropriate reaction under given circumstances.

2.2 Representation

Representation means mapping (f) characteristics of empirical phenomena (P_e) into values of parameters in an artificial world (P_a). Thus a representation is determined by $\{P_e, P_a, f\}$.

This means that we need a (formal) system to describe P_e P_a and the mapping "function" f.

It must be stressed that mapping does not necessarily mean mimicking or portraying. For example, a plane that flies does not mimic the behaviour of a flying bird.

2.3 Model

A model is a simplified representation at a conceptual level of (a part of) the real world and/or the way it behaves, that suffices to make some deductions concerning the real world and/or it's functioning. A model consists of components and the relationships between those components, which are generally cause-effect relationships. A model can be visualized in some graphical form.

For example, the three stage-model of memory (here rendered in its oversimplified form).

The graph below means that information that is kept by receptors is temporary stored in the sensory memory, is then transferred to the working memory, and after elaboration in this part, is permanently stored in the long term memory. Furthermore, information can be retrieved from the long term memory by the working memory (and then used for some behavioural purposes).

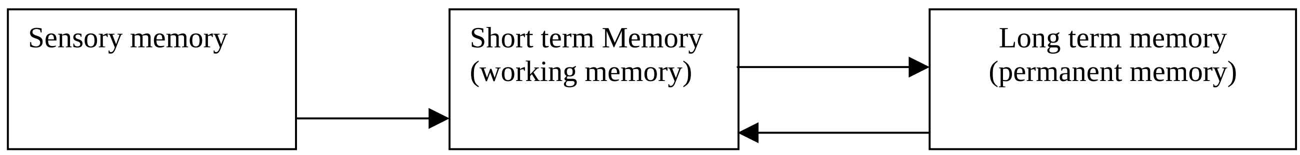


Figure 1: Example of a Model

Essential characteristics of a model are:

- Reduction of the complexity of the real world
- Highlighting what is considered as essential or important
- Transparency of the relationship(s) between the components
- Putting the representation in a certain perspective, based on the choice of the components and the relationship between components
- Productivity: models allow for the discovering of (working) hypotheses, for new insights at a certain level of quantification, for the verification of the impact of changes (by changing

starting values, by adding or dropping components and/or relationships: cfr path analysis; e.g. LISREL).

A model implies that:

- A choice must be made which characteristics will enter the model and which not
- Therefore, one or more selection criteria are needed (which define the perspective)
- Characteristics are to be reflected in variables that can be quantified

In the context of this LTSS the notion "model" does NOT refer to the physical device that shows how something works in reality (e.g. a model of the wings of a plane and the air streams around it) nor to the notion as defined in social learning, i.e. the person whose behaviour is mimicked.

Aspects of modelling human behaviour

- Given that human behaviour is purposive, not only the behaviour itself must be modelled but also the goal, which has to be converted in a *SMART objective* (**S**pecific, **M**easurable, **A**cceptable, **R**ealistic, **T**imed).
- This objective is the touchstone in determining what is the optimum behaviour under the given circumstances.
- In its most simple expression modelling behaviour means: determining initial values for P and S (input), run a process (throughput) which lead to an outcome (output); i.e. a change in P and/or S.
- The model requires a "level of behavioural analysis":

  A single action
  A contingent series of actions
  A series of actions executed in parallel
  } by { an individual / a team / an organisation }

HBR modelling relies, as to the content of the models, on:

- Military experience
- Findings of human science research

The latter defines and structures, using established terms and theories, all relevant types of human behaviour. There are additional concepts that should be used as in for any further discussion and HBR science development. These concepts are:

- Individual
- Team
- Group (small group and large group)
- Organisation
- Crowd
- Public opinion (shaped by the media)

The basic concept is that of the individual.

Team, group, organisation and crowd are specific collections of individuals, which are defined according to different behavioural goals and interactions (both within the collective entity and as a collective entity interacting with others).

As for public opinion see Chapter 4 Section 4.2.1.

The scientific task with respect to the individual, team etc is to find and define the specific goals and interactions of the individual and of each collection of individuals, thus specifying what goals and interactions:

- build a military team from few skilled individuals
- make a small or a big group under certain special conditions
- create or change an organisation
- constitute a crowd, when many people suddenly behave in a uniform manner.

The task of modelling individuals, teams etc is

- to take the typical behaviour expressed in goals and interactions
- to put quantitative measures on the internal and external behaviour of the respective entity.

So far the characteristic behaviours that differentiate a team from any smaller or larger group or organisation or crowd have not been elaborated to the point where they can be used for modelling in a military context. Therefore, the first scientific endeavour is to collect on a systematic and scientifically accepted manner this body of knowledge, which can then be used by for modelling purposes.

- For each characteristic (= variable) a scale of measurement1 has to be determined and "baseline", i.e. an initial parameter value.
- A distinction has to be made between trait and state:
- a *trait* is a covert cross-situational and cross-temporal stable characteristic of a person but which expression is modulated by the perceived situation.
- A state is a condition not manifesting any marked change with respect to some quality or property.

For example, a person who shows often anxiety in his behaviour in different circumstance is an anxious person. This person is characterised by anxiety as a trait.

A person who is rarely seen anxious but has been confronted with a traumatic event is temporary anxious. This person is in a state of (intense) anxiety.

[1] A scale is the triple {U, N, f} in which U stand for the observed variations in the empirical phenomenon, N for the numerical values that are assigned to the observed "states" of the empirical phenomena using a function f.

2.4 Simulation

Simulation means:

- A method to implement a model in some environment and/or in a device, which may be totally or partially artificial (instead of real).

- A technique for analysing, testing, evaluating the effect of some values of the parameters of the model on other parameters. For example, a decision making process (e.g. choose a tactical plan among three alternatives) can be simulated on a computer, using some algorithm (among others, a decision tree).

- Using a tool (a simulator) for instruction or training purposes, e.g. flight simulator.

The following categories of simulation are used commonly in the NATO context/language of Modelling & Simulation:

Live simulation: real humans operate real equipment in a real environment except for some parts or aspects (e.g. OPFOR is not a real foe but a unit that acts as enemy; blank ammunition or hit/kill indicators instead of wet ammo; terrain is a training camp or a civilian area but not the operation zone)

Virtual simulation: real humans operate simulated equipment in a simulated environment (e.g. Computer Assisted (Command Post) Exercises; a pilot in a flight simulator).

Constructive simulation: simulated people (or units) operate simulated equipment and/or behave in a simulated environment. The intervention of real humans is limited to “initialise” the simulation run.

2.5 Instruction/learning

During instruction, a person learns a *new* cognitive, psychomotor or socio-affective “item” relevant to the organisation he is part of. Instruction takes place in a specific environment such as a school. Instruction is given by qualified personnel who are required to show the optimal behaviour and is thus better skilled than the trainee.

Learning in this sense, is defined as a long lasting desired behaviour modification under the influence of the repeated exposure to adequate stimuli. The learning process is (constantly) monitored by the instructor. The behaviour of the trainee is corrected on the spot. Feedback is procured during and after the training process.

E.g. an officer learns how to write an operations order for his subordinates, a soldier learns how to aim and fire a weapon, a new formed squad/crew learns what cohesion means to their functioning as a group.

2.6 Training

Training means to *repeat* a learnt behaviour in order to enhance the performance, or to internalise a norm, or to develop an attitude in a rather simplified environment. For example, a pilot is trained in applying flight procedures (in a simulator); discipline is trained throughout different situations, which require obedience to the established rules. Training does not differ from instruction with respect to the trainer/trainee interaction.

2.7 Exercise

An exercise aims at using what has been learned and trained but now in a less or more real like situation. In an exercise real people use real means in a real environment. For example, command post exercises; or full troop exercises live firing exercises in battle runs.

An exercise is controlled by an observer-controller (or a coach) who does not intervene in the course of action, but who is responsible for detailed after-action review. Moreover, the observer is not necessary better skilled than the people who are exercising.

2.8 Operation

Operation refers to real life (military) activities in order to realise a given mission. For example, the deployment of a task force, a brigade attack, peace keeping as a particular case of peace support operations.

2.9 Performance

Performance refers to the behaviour itself or its result/outcome in one of the following forms:

- Executing and finishing a certain task. For example, fire until hit.
- A numerical expression related to the behaviour. For example, defend a position during 4 hours
- Expression of the competence, moderated by some personal and/or situational variables. For example, physical performances under bad weather conditions (too cold, too warm) are lower than under good weather conditions.

2.10 Competence

Competence means the best possible behaviour of a given person with respect to certain ability for a particular job or vocation. Competence is a higher order notion for a series of performances that meet high standards. For example, a competent leader is a leader who is often successful in conducting operations (of different kind).

2.11 Optimal behaviour

Optimal behaviour is the best possible performance given under the circumstances; i.e. taking personal and situational constraints in to account; thus: B=f (P,S). This means also that an optimal performance is lower than or equal to the maximal performance (=competence).

2.12 Situational awareness

Situational awareness is the result of the perception of a number of elements in the environment within a given timeframe and space, their meaning with respect to the mission at hand and their possible evolution in the near future that must be taken into account in determining one’s own behaviour.

Situational awareness is multidimensional because it deals with spatial information (e.g. where is who/what), with information contained in the mission (e.g. what to do within which time interval), own means (e.g. “readiness” of crews) and available resources (e.g. which fire support).

2.13 Validation, Verification, Accreditation

- *Validation* means determining the degree to which a model is an adequate representation of the real world (or a part of it) for the purposes it has been conceived for.
- *Verification* refers to the process of determining to what extend the implementation of a model corresponds to the design specifications determined by the customer and of providing the proof that the model runs (as its has to run).
- *Accreditation* is the official certification that a model or simulation is acceptable for use with respect to its purpose(s).

3 A Concise Structural Approach of HBR as a Framework

This section tries to give a global approach of HBR in military applications. However, a global theory cannot be the goal of this LTSS and must be postponed, when more information about the practical use of HBR for any field is available. Therefore, we have to limit an approach to a framework.

3.1 General Approach

The concise theory must avoid two fallacies:

- on the one hand to be too short and therefore trivial
- and on the other hand to be too scientific and lengthy.

This dilemma will be avoided by presenting a logical deduction and phenomenological description of those human *behaviours*, which are essential in military operations (including CRO) and the way they should be represented for analysis, training and simulation.

By logical deduction it is understood that the theory is coherent in itself, and not just an arbitrary collection of abstract statements.

By phenomenological description a description is meant, which focuses on typical and relevant events and describes them as close to (military) common sense as possible.

3.2 Objects of HBR-Theory

The ultimate goal of HBR is (as this is the case in every military simulation), to represent behaviour that is *typical and relevant* in military operations. Relevant is every human behaviour, which is decisive for the mission success. But in order to make it the object of a theory and therefore the object of well elaborated models and simulations, the human behaviour must be "reduced" to certain "system simplifications".

What is the "level of detail" that must be employed to describe the human *behaviour*?

The level of detail of a rough task analysis but reduced to general mental (i.e. cognitive, psycho-motor, social and physiological) functions (examples see below).

What is relevant for the *representation* of behaviour?

Every behaviour that is needed in analysis, training and simulation is considered as relevant.

3.3 Elementary Behaviours (mental functions)

The following is a taxonomy, which lists mental functions in a systematic way appropriate for modelling.

- ➢ Actions – Observable behaviour in the outside world
  - ♦ Interactions with real objects and real environment - physical skills (e. g. driving a car, digging a hole)
  - ♦ Symbolic interactions (e.g. communication by speech, in documents by gesture)
  - ♦ Social interactions (e. g. speaking to another person)
    - ▪ Interpersonal relations (with superiors, subordinates, colleagues)

        - Group dynamic influences (small group effects; e.g. cohesion)
        - Organisational influences

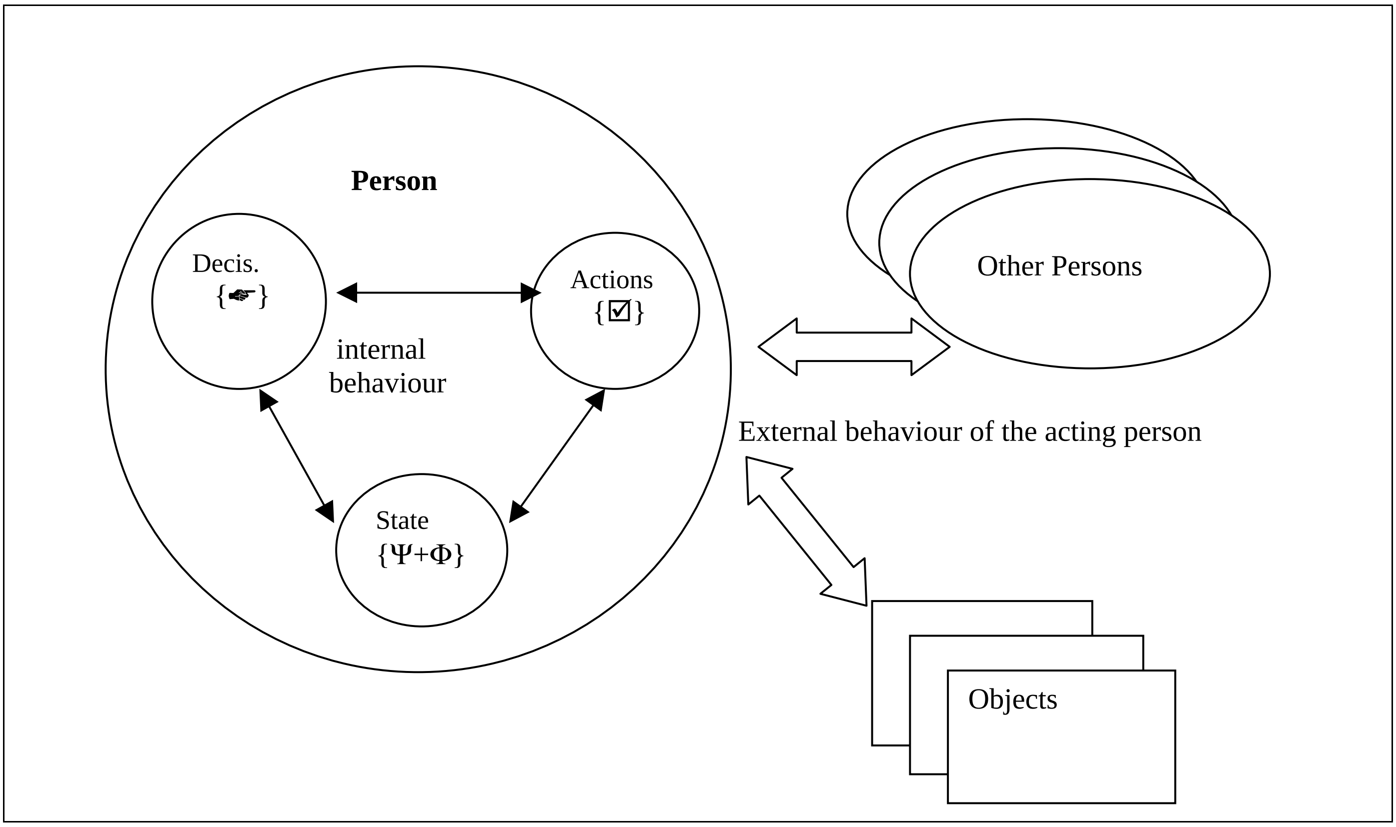
- Decisions – not directly observable behaviour within the person – making up one's mind.
    - Situational awareness (e. g. observing an area)
    - Information collection (e. g. map reading)
    - Information processing – from sensory input to mental models (e. g. identifying an object as foe)
    - Schemata (e. g. knowledge, skills)
        - Declarative knowledge
        - Procedural knowledge and skills
        - Meta-cognitive skills (control of behaviour, evaluation)
    - Deciding for action (e. g. shooting to a foe object, giving an order to shoot)
- Psychical and physiological traits / states
    - Age
    - Values (e. g. personal standards, cultural values, beliefs, attitudes)
    - Moods / emotions (e. g. anxiety)
    - Motives (e. g. high performance motive)
    - Alertness / vigilance (e. g. high vigilance)
    - Stress (e. g. loss of sleep, heavy workload)
- Dynamic changes of behaviour
    - Learning and Instruction (slow)
    - Traumatic experience (quick)
    - Duration of stress

For the scope of this paper it is sufficient to use this simple taxonomy. It can be used for three purposes:

- to describe a global structural concept of the interrelationships between the behaviours (human behaviour "model")
- to establish a list of compound behaviours
- to evaluate the feasibility of special elementary human behaviour model
- to define the different kinds of representation for analysis, training and simulation.

3.4 Compound Behaviours

No single behaviour type exists by itself. All types are always combined and have to be represented at least together with some of the other types. The global behaviour model, therefore, serves the purpose of identifying the interrelationships of the behaviour types. Internal behaviour (within the person) and external behaviour (towards other persons and with objects in the environment) are combined into compound behaviours. See the following picture.



Picture 2: Person and its behaviour in an environment

➢ Objects and persons provoke decisions and actions.
➢ Motives influence the choice of individually available schemata.
➢ Schemata influence decisions.
➢ Decisions make persons act.
➢ Age values, moods, alertness and stress moderate decisions.
➢ Age values, moods, alertness and stress moderate directly actions.
➢ Actions change values, moods, motives, alertness
➢ Actions change decisions.
➢ Decisions change values, moods, motives.
➢ Objects, persons and stress cut off the decision-making processes.

Table 1: Internal compound behaviour

➢ Actions change objects.
➢ Actions influence other persons.
➢ Other person’s actions and objects of the environment make persons change their psychical and physiological states.

Table 2: External behaviour

3.5 Data Sources

Every behaviour produces different data. The data can be classified into two groups:

- Directly accessible data, which are subdivided into
  - measurable and observable data {m+o}
  - only observable data {o}
- Data that must be constructed indirectly by theories {c}.

Applying this simple data taxonomy to the behaviour types, it can be seen, whether it is (relatively) easy to build models about the behaviours in question (on model building in HBR see below):

- Directly accessible data {m} and {o} make model building easier; many models do already exist and are used
- Constructed data make model building difficult.

The reason lies in the validation and accreditation of the data. Directly accessible data can by verified through objective methods and the corresponding theory. Constructed data are entirely based upon the validity of the theory.

Directly accessible data can be sub-divided into:

- Observable data at a high level of measurement; i.e.
  - on an interval scale. For example: body temperature, precision of aiming at a target.
  - on a ratio scale. For example: speed of movement, estimation of the distance to a target.
- Observable data at a low-level of measurement, i.e.
  - at a nominal level or classifying objects. For example, friend or foe, identifying a object as a main battle tank
  - at an ordinal level or ordering objects with respect to a certain criterion. For example, “intensity” of threat of different enemy manoeuvres.
  - at the hyper ordinal level or comparing differences between (two) sets of two objects. For example, different balances of forces.

Unobservable data refer to psychological constraints. The way they are “operationalised” i.e. made observable. The process of operationalisation determines also their level of measurement.

For example, intelligence is made observable through the responses to an intelligence test and can be expressed in an intelligence quotient IQ (which is at the interval level). For example, group cohesion can be expressed through a ranking of the co-workers by each of the group members. Using multi-dimensional scaling these rankings can be converted into a map with distances between the members. The greater the distances the less cohesion is.

Complex constructs, for example combat readiness –involving several domains of human behaviour (i.e. cognitive, motor and/or socio-affective) constitute a specific challenge for modelling because the whole is more and something other than the sum of its components. Therefore, it is suggested to approach such constructs in a holistic way rather than in an analytical way.

Behaviours	**Data**
Actions {☑}	
Interactions with real objects and real environment (e. g. driving a car, digging a hole)	m+o
Symbolic interactions (e. g. writing)	m+o
Social interactions (e. g. speaking to another person)	m+o
Decisions {✒}	
Situational awareness (e. g. observing an area)	o
Information collection (e. g. asking an expert)	o
Information processing (e. g. identifying an object as foe)	o
Deciding for action (e. g. shooting to a foe object, giving an order to shoot)	m+o
Psychical and physiological states {Ψ+Φ}	
Values (e. g. cultural values)	c
Moods / emotions (e. g. anxiety)	c
Motives (e. g. high performance motive)	c
Alertness / vigilance (e. g. high vigilance)	m+o
Stressors (e. g. loss of sleep, heavy workload)	m+o
Schemata (e. g. knowledge, skills)	c
Dynamic changes of psychical and physiological states {Δψφ}	
Learning (slow)	c
Traumatic experience (quick)	o
Duration of stress	m+o

Table 3: Matrix of elementary behaviours and the related data sources

4 Model Building in HBR

Models of human behaviour are always models of compound behaviours. It is still uncertain, whether an all-embracing model of *the* Human Behaviour is feasible and necessary for military simulation. The following matrix gives an overview on the feasibility models. Every compound behaviour is analysed as to whether models are

- Easy to develop, even if they do not yet exist {e}
- Difficult to develop, even if they already exist {d}
- Impossible to develop {i}.

	Feasibility of Model Building	
Behaviours	Easy	Difficult
Objects and persons provoke decisions and actions.	e	
Motives influence the choice of individually available schemata.		d
Schemata influence decisions.		d
Decisions make persons act.	e	
Values, moods, alertness and stress moderate decisions.		d
Values, moods, alertness and stress moderate directly actions.		d
Actions change values, moods, motives, alertness		d
Actions change decisions.		d
Decisions change values, moods, motives.		d
Objects, persons and stress cut off the decision making processes.	e	
Actions change objects.	e	
Actions influence other persons.		d
Other person's actions and objects of the environment make persons change their psychical and physiological states.		d

Table 4: Matrix of behaviours and the feasibility of model building

Conclusion: There is no human behaviour, which cannot be made the object of a model. However, the majority is difficult to model and relies mainly on theories of the elementary behaviours (mental functions), which themselves are difficult to validate.

5 References

Dompke, U., Scheckeler, K., Final Report on Long Term Scientific Study (LTSS/SAS-017) on Human Behaviour Representation (HBR) Technology, RTO-TR-047, AC/323(SAS-017)TP/25, Brussels, 2001

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Human Behaviour Representation - Application Areas

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Abstract

This paper is taken from the Final report of LTSS SAS-017 on Human Behaviour Representation It gives an overview on the different applications of HBR. It starts with the new military environment. Based on this description the applications in the areas of Instruction, Training and Exercise, Defense Planning, Acquisition and Support to Operations are described. A summary on the importance of HBR is given at the end.

1 Future Military Environment

General. To accurately determine future military requirements NATO's missions must be considered within the context of the predicted future security environment. Even though the security conditions have greatly improved after the end of Cold War, there are still residual risks to the Alliance. Therefore NATO's first mission is still **Article 5 Operations**. These situations comprise all potential threats and risks of armed attack against one or more NATO members. Such situations can range from relatively small sub-regional problems to threats involving more than one NATO Strategic Commander's (SC's) area of responsibility (AOR). Large scale Article 5 Operations on this scale are only considered to be possible after an extended build-up.

In addition new risks have emerged and more can be expected. It is not possible to predict either the time or the place these risks may break out into future conflict. Therefore the future environment will be characterised by variety and uncertainty. Geopolitical changes since the end of the Cold War is forcing NATO to look well beyond its traditional area of responsibility. The focus of geo-strategic analysis must be re-oriented to include all areas where NATO forces might be deployed. Potential crisis regions, their security impact on Alliance nations and routes to these nations are therefore of direct interest to NATO. These missions are called **Crisis Response Operations (CRO).**

CRO operations are composed of

- Peace Support Operations (PSO) and
- Other Security Interests (OSI).

The following sections cover all the different types of CROs NATO may be involved in the future.

Peace Support Operations: PSO are multi-functional operations conducted impartially in support of a UN/OSCE mandate involving military forces and diplomatic and humanitarian agencies and are designed to achieve a long term political settlement or other conditions specified in the mandate. They include peacekeeping and peace enforcement as well as conflict prevention, peacemaking, peace building and humanitarian operations.

Paper presented at the RTO SAS Lecture Series on "Simulation of and for Military Decision Making", held in Rome, Italy, 15-16 October 2001; Stockholm, Sweden, 18-19 October 2001; Virginia, USA, 23-25 October 2001; The Hague, The Netherlands, 10-11 December 2002, and published in RTO-EN-017.

OSI: Potential threats to Alliance vital interests can result from a number of causes. Such risks are not geographically limited to areas in the areas contiguous and peripheral to NATO territory. These include:

(1) Military significant violation of arms control treaty obligations, including non-proliferation agreements.

(2) Threat to use military force, including coercion.

(3) Acts of terrorism or sabotage affecting Alliance territory.

(4) Disruption of economic lifelines, lines of communication, public service infrastructure by blockade, sabotage or other use of force.

(5) Border violations and incursions as well as hostile violations of Alliance territorial waters and airspace.

(6) Missile or aircraft attack against Alliance members.

(7) Spill over of conflict from beyond NATO's Area of Responsibility (AOR).

(8) Armed attack against forces, vessels or aircraft of any NATO member in NATO's AOR or beyond NATO's AOR during PSO.

Further, although support to UN peacekeeping operations "is not, in principle, geographically limiting, emphasis should nevertheless be placed on geo-strategic aspects relevant to the risk of spill over of crisis and conflicts into the NATO area of responsibility

Regions within these geo-strategic areas, where future NATO-led operations were thought to be possible, were examined to derive a wide range of likely environmental and geographic characteristics under which CRO could be carried out.

Peace Support Operations are undertaken under Chapter VI or VII of the UN Charter and divided into the following types of operations:

Peacekeeping: Peacekeeping operations are generally undertaken under Chapter VI of the UN Charter and are conducted with the consent of all Parties to a conflict to monitor and facilitate implementation of a peace agreement. Possible tasks for peacekeeping operations include observer missions, interposition force operations and transition assistance.

Peace Enforcement: Peace enforcement operations are undertaken under Chapter VII of the UN Charter. They are coercive in nature and are conducted when the consent of all Parties to a conflict has not been achieved or might be uncertain. They are designed to maintain or re-establish peace or enforce the terms specified in the mandate. Possible tasks for Peace Enforcement operations include: enforcing sanctions, establishing and enforcing no-fly zones, protection of humanitarian operations and establishing and protecting safe areas or exclusion zones.

Conflict Prevention: Activities aimed at conflict prevention are normally conducted under Chapter VI of the UN Charter. They range from diplomatic initiatives to the preventive deployment of forces intended to prevent disputes from escalating into armed conflicts or from spreading. Conflict Prevention can also include preventive deployment, surveillance, early warning, and implementation of embargoes in support of sanctions.

Peacemaking: Peacemaking covers the diplomatic activities conducted after the commencement of a conflict aimed at establishing a cease-fire or a rapid peaceful settlement. They can include the provision of good offices, mediation, conciliation and such actions as diplomatic pressures, isolation or sanctions.

Peace Building: Peace Building covers actions, which support political, economic, social and military measures and structures aiming to strengthen and solidify political settlements in order to redress the causes of a conflict. This includes mechanisms to identify and support structures, which will tend to consolidate peace, advance a sense of confidence and well-being and support economic reconstruction.

Humanitarian Operations: Humanitarian operations are conducted to alleviate human suffering. Humanitarian operations may precede or accompany humanitarian activities provided by specialised civilian organisations. Possible tasks for Humanitarian Operations are: protection and transport of humanitarian aid convoys, maintenance, repair and creation of routes and critical infrastructure, medical support, assistance in the relocation of return of refugees and humanitarian de-mining operations.

Risks of a wider nature are defined in NATO documents as including “international terrorism, radical trans-national movements, territorial disputes, disruption of the flow of vital resources and mass migration...the proliferation of WMD in a global as well as European context.” For the purposes of the review this information was used to define two categories: Economic and Military-Political. Within each category it was assumed that NATO military forces could be required to execute the following missions:

(1) Economic.

- (a) Ensure free movement of vital resources along strategic lines of communication.
- (b) Prevent interference with the availability of vital resources (oil, minerals etc.)

(2) Military-Political.

- (a) Assist in maintaining regional military-political stability.
- (b) Extract NATO member forces engaged in a UN or OSCE-led PSO when threatened with serious aggression.
- (c) Execute deterrent actions against states involved in terrorism or terrorism support.
- (d) Execute deterrent actions against states involved in the proliferation of and/or potential use of weapons of mass destruction.
- (e) Protect NATO territory from the spill over effects (refugees, mass migration, organized crime) of peripheral region instability.

The area peripheral to NATO’s AOR should be of primary focus however, since the range of potential Alliance involvement is not in theory geographically limited, an initial worldwide review should be carried out. All areas/regions were assessed to determine those that were possible candidates for a future NATO led CRO. This assessment should be based on the following filtering process:

(1) Potential for political/ethnic/social/economic instability leading to conflict

(2) Existence of regional organisations or alternative support structures that could undertake the operation

(3) Degree of NATO acceptance within the region

(4) UN/OSCE mandate likely

(5) NAC approval likely

In general, the changing in threats to NATO countries drives the need for advanced HBR and the increased emphasis on non Article 5 missions described above. NATO countries no longer exist in a world of blue and red where the major threat to security comes from one block of nations. Instead, NATO faces a difficult to perceive future where the only certainty is change: Changes in threats, changes in adversaries, and changes in the missions NATO forces are expected to accomplish. Against this background the only certainty is that NATO forces must become more flexible and adaptable.

In summary, the future military environment of NATO will most likely be dominated not by Article 5 missions, but rather by CRO missions. This change will severely challenge NATO. NATO will not be able to rely on existing war plans and doctrine (as it does for Article 5 missions), but instead be forced to develop plans and procedures for CRO missions on an as required basis. NATO will have to become more flexible and adaptable, ready to respond to a wide range of possible courses of actions. HBR can help them achieve this goal.

2 Application Areas

There are many potential NATO military applications for HBR. In this section we discuss how HBR may be used to support training and exercises, defence planning, acquisition, and support to operations. As will be seen below, in many of these application areas HBR is a component of some other technology (e.g., modelling and simulation) that is providing support to the NATO activity; in other instances it is a supporting technology in its own right. The discussion is not meant to be exhaustive consideration of military applications for HBR. Rather, it will highlight some of the applications that can be readily foreseen.

In general, the changing in threats to NATO countries drives the need for advanced HBR and the increased emphasis on non Article 5 missions described above. NATO countries no longer exist in a world of blue and red where the major threat to security comes from one block of nations. Instead, NATO faces a difficult to perceive future where the only certainty is change: Changes in threats, changes in adversaries, and changes in the missions NATO forces are expected to accomplish. Against this background the only certainty is that NATO forces must become more flexible and adaptable. HBR can help them achieve this goal

2.1 Instruction, Training and Exercises

Within NATO training and exercises encompasses three sub-areas, namely instruction, training and exercising. The detailed definitions of these terms can be found in chapter 2, para 1. For this discussion, it suffices to retain that instruction and education refers to the acquisition of skills by an individual or group for the ***first*** time. Training follows instruction and is aimed at ***improving the performance*** of individuals and teams at employing their newly acquired skills and knowledge. Exercises follow training; their objective is threefold. Exercises aim at maintaining skills acquired during training at a specified level of performance. They are intended to enable teams and individuals to generalise the knowledge that they have acquired through training. Exercises also develop the knowledge about the conditions in which to best use specific skills.

In the progression from instruction to exercises, the environment that is used to achieve the transfer of knowledge becomes more complex and the understanding about the use of the transferred knowledge increases in the team or individual.

An important aspect of knowledge transfer is the ability to measure performance of the individuals or teams involved in instruction, training and exercising. While performance measurement can be specified and executed well in instruction, it becomes increasingly difficult in training and appears to be ill-specified in exercising. However the quality of knowledge transfer is directly related to the capability to measure performance and provide feedback.

In the new security environment that has emerged over the past ten years, we have seen a rapid change in many NATO nations armed forces. They have transitioned from an army based on conscription to fully professional armed services. This new form of organisation relies on many persons to join the ranks of the armies for short term contracts. However the sustained economic growth has made it difficult for many nations to attract suitable people and at the same time caused a considerable amount of highly skilled and experienced professionals to leave the armed forces. Therefore the need for a sustained training and exercising environment providing a consistent level of knowledge transfer has grown.

At the same time, many operations are conducted on an “ad hoc” voluntary participation basis by nations that place a considerable and sustained demand on limited personnel resources. Since planning for these operations cannot be foreseen and incorporated in planned training and exercise events, the training environment must highly configurable and composable with the relevant elements in order to prepare personnel participating in these operations effectively. Furthermore, good performance measurement is required to establish the ability of the personnel to carry out their tasks in an often highly visible environment from a political and media perspective. These inherently multi-national operations almost invariably involve non-NATO personnel who are unfamiliar with NATO tasks and procedures and need to be trained and exercised to work together in an effective manner.

Also co-operation with non-governmental and private volunteer organisations has increased considerably. Since the military forces are often responsible for the overall security in the area and for the protection of local populations as well as external organisations, the representatives from these organisations also need to be trained e.g. mine awareness.

It should also be noted that a new problem is emerging as a result of the many parallel operations that are being conducted by forces from NATO nations. Due to the length of these commitments, it is becoming increasingly difficult to ensure that military personnel is trained on the full spectrum of tasks that they are expected to be able to deal with. Therefore, training and exercising is required whilst personnel is deployed and will need to be inherently distributed.

Overall there is a greater need for a training and exercising environment that can be configured rapidly and made widely available to a broader community of people requiring their skills to be developed in a co-ordinated and consistent manner. Also there needs to be greater emphasis on a verifiable level of skill in personnel because the room for error has become extremely small due to the high degree of media coverage and to the stringent and detailed political guidance.

The following sections will focus on the need for formal representations of human behaviour for the processes of instruction, training and exercises. The importance to address the development of such behaviours rapidly will be argued. Section 3.3 will contain the expected benefits of developing formal representations of human behaviour.

2.1.1 Instruction and training

In instruction, material is usually presented by a lecturer or a computer-based tool to an individual and can cover a wide range of topics (e.g., anything from technical training on how to use a specific system to the procedures for Transfer of Authority). Material is absorbed by the individual or group and a number of tests are conducted to verify the acquisition of knowledge or skills. Based on the results of the tests, material is presented again or the trainees can move on to another phase of the instructional process. When the knowledge or skills are considered acquired, training can start. The goal will be to improve the performance of the trainee(s) in applying their new skills and to start the acquisition of meta-knowledge about the conditions of usage of these skills. In order to stimulate the development of meta-knowledge and gather a wider set of measurements, training requires the environment to be more complex and the set of scenario's needs to be more diverse than in an instruction context. Using this description, the following elements can be identified as composing the instructional environment:

- The individual or group of trainees. Their level of knowledge needs to be determined throughout the learning process. It is also necessary to define a reference trainee for performance measurement. The reference trainee can be either an average derived from the performance of previous trainees, an internal reference, or an ideal trainee defined by a set of experts, an external reference.

- The entities that the trainee(s) interact with, from a physical and mental perspective

  - Inanimate systems

  - Individuals: team members, leaders, subordinates, opponents, bystanders

  - Teams: well organised, goal-orientated individuals, displaying a high degree of cohesion and mutual support

- Groups of individuals: loosely cohesive, temporary groups of individuals e.g. crowds
- Organisations: subordinates, superiors, peers, opponents, NGOs, PVOs, governmental elements, media
- Platforms operated by humans

These entities should behave in a consistent and reproducible manner to provide all trainees with a verifiable and objectively measurable level of performance. They need to be fully interoperable at equivalent and different levels of granularity, allowing the designers of the knowledge transfer task to configure the instructional environment in the most effective manner. From a technical perspective they need to be able to operate in a distributed environment over large distances.

- The instructor who manages the knowledge transfer process by controlling the presentation and illustration of instructional material, the steps taken by the trainees in acquiring knowledge and who measures the performance of trainees.

A good instructor will adapt the instructional strategy to the background and to the progress that the trainees are making. It is also necessary that the instructor behave in a consistent manner regardless of the trainee(s) especially when measuring the performance of trainee(s) and judging their progress. The instructor contains a repertoire of teaching strategies and a representation of an expert's knowledge to teach both domain knowledge and expert problem solving strategies.

From a technical perspective, the instructor should be able to operate on the equipment used by the trainee and intervene with it to provide the trainee with a continuous ability to maintain skills and call upon remedial training when required. Hence the instructor should be able to transition from its initial knowledge transfer function to a coaching and assistant role when the trainees starts to perform the newly acquired tasks in his or her working environment.

Automated representations of human behaviour of the elements described above are necessary to improve computer-assisted instruction, specifically the form of instruction known as intelligent tutoring. Traditional computer-based instruction tools use the trainee's response to multiple-choice questions to direct the instructional path. If the trainee performs poorly on a test, instructional material is presented again, usually in a slightly different format. These tools also attempt to anticipate all possible trainee errors and seek to provide appropriate remedial instruction. However, such an approach fails when trainees interpret instructional material in an unanticipated incorrect manner. In this situation, the system cannot generate an explanation that will resolve the student's misunderstanding and the student's learning is impeded. Hence static models of the trainee and of the instructor do not provide a sufficiently flexible and responsive environment. In summary, there is a need for a formal approach to adaptive and interactive treatment of the knowledge transfer process also referred to as adaptive treatment interaction ref. Snow, Stanford.

Automated implementations of representations of the human behaviours described above are essential in achieving the standardisation, objective training, composability and distribution requirements mentioned with each of the representations described above.

In order for NATO staffs to efficiently train, the information they receive and the response of their opponents to their actions should be as realistic as possible. Recent advances in modelling and simulation technology have dramatically improved the presentation and display of information for training purposes. However, these simulation environments rely almost completely on role players for the representation of human behaviour at the level of interaction with the staff being trained. They also neglect to represent the human behaviour aspects for simulated entities. Human role players are usually required in large numbers and therefore poorly qualified to perform their function. Recent training events conducted with fewer professional role players have shown that this can be overcome. However this approach is not sustainable for larger events from a cost perspective. In any case, human role players always introduce implicit bias e.g. risk taking. Formal representations of human behaviour that can be automated are necessary to provide a realistic representation of all human or human-operated entities. These models are required to ensure a consistent quality of training and to enable the use of more complex training scenarios.

2.1.2 Exercises

Exercises are formalized gatherings of a particular command echelon in which trained individuals practice their skills in a wider military context. Exercises may be conducted at strategic, operational, and tactical levels and are intended to assess the echelon's ability to execute selected elements of its mission. As noted in a NATO report on computer-generated forces (reference required), post-Cold War exercises have become more complex due to the lack of detailed contingency plans and the resulting greater effort required for designing exercises. In addition, the range of scenarios that needs to be exercised has increased to an expanded mission set (e.g., peace keeping and humanitarian aiding) and the increased number of agencies and governments that NATO works with (e.g., Private Voluntary Organizations, Non-Governmental Organizations, and Partnership for Peace nations).

For exercises all aspects discussed for instruction and training apply except for the role of instructor. Since the exercising staff is assumed to have achieved a good of level of knowledge, the role of instructor is replaced by the role of observer. Observers will have access to the perception of the exercising staff as well as to the real situation data. Therefore the observer role is capable of assessing performance and of providing feedback. Co-ordination between observers and exercise directing staff is necessary to adapt the flow of the exercise similar to adapting the training strategy in order to meet exercise objectives. In order to provide a consistent observation capability and allow observation to take place for each individual and group participating in an exercise, an automated representation of the observer is required due to the large number of personnel participating in exercises and the many group activities taking place in parallel.

The requirement for automated human behaviours as described in the previous section is also more pressing in an exercise environment because the environment is more complex in terms of numbers and types of entities, the combination of entities of different levels of aggregation e.g. individual leaders, crowds, aggregated military units and the potential requirement of decomposing aggregates to answer specific information requirements.

Compared to training, exercises add the aspect of C3I SYSTEMS interfacing. There are two aspects to this form of interfacing. The first aspect requires the simulation environment to be capable of consuming guidance from the exercising staff and from the exercise control staff and to develop the necessary plans and actions autonomously. Therefore models of the cognitive aspects of the receiving entities need to be represented as well their physiological and socio-affective characteristics. The second aspect is the generation of information from the simulation environment in a form and content that is required and expected by the information systems supporting the exercising staffs. This information is both structured and unstructured, the latter being mainly assessments of situations and intentions. In current simulation environments, a combination of automated interfaces and role players perform these tasks. The automated interfaces tend to support the structured information flow with fixed information pathways. Role players are necessary to generate unstructured information and reconcile inconsistencies in guidance. In order to reduce the considerable amount of role players that is currently required, automated models of human behaviour need to be developed. They are also required to improve consistency.

Furthermore composability and interoperability is necessary to allow the rapid preparation of effective exercise designs, which is becoming increasingly important when responding to unexpected crisis situations.

In view of the complexity of exercises, performance measurement is considerably more difficult and requires data collection to be pervasive. Therefore the development of the automated observer representations discussed above is critical for providing good after-action review.

2.2 Defence Planning

Defence Planning in NATO is the identification of future requirements to address anticipated missions, five to fifteen years in the future. Defence Planning identifies required capabilities to solve future problems; it can be contrasted with Operational Planning, which is concerned with making the best use of available forces to tackle near term problems.

The goal of Defence Planning is to identify military assets capable of responding to a wide range of military situations. Defence planning is subdivided into the following disciplines:

- Force Planning
- Armament Planning,
- Reinforcement Mobility Planning
- Logistics Planning
- Stockpile Planning,
- Nuclear Planning
- Civil Emergency Planning
- Infrastructure Planning,
- Command Information System Planning

Support to Defence Planning within NATO, for the most part, is provided by specialised constructive models. Within NATO, there is currently a range of limited models covering everything from individual platform engagements to force-on-force theatre level campaigns. A recent NATO report on modelling and simulation identified several shortcomings with existing models, primarily in the areas of evaluating new missions, understanding political-military decision-making, and conducting joint operations (reference NATO M&S Report). HBR research will play both a direct and an indirect role in improving NATO defence planning.

One of the most serious gaps in NATO defence planning is the lack of adequate means to evaluate new missions. Since the end of the Cold War, the range of potential NATO missions has expanded considerably (e.g., NATO, collective defence and NATO-Plus, Non-Article 5 missions), as has the range of potential NATO allies and adversaries. This increased range of missions and actors has created a significant need for tools to support concept development and experimentation, particularly in the areas of requirements definition, doctrine development and the tactics evaluation. NATO is looking to advances in modelling and simulation technologies to fill this need. One of the most critical component technologies, as identified by a recent NATO report, is HBR (need reference to NATO M&S report). Advanced HBR models, similar to the types described in the previous section, are required to reduce the cost and increase the realism of the constructive models used by defence planners.

For example, new models are needed to analyse both information warfare and peace support operations. To accurately model the threats and opportunities brought about through advances in the conduct of information operations and warfare will require the development of very high fidelity HBR models of individuals and organisations. Such models will have to depict the flow of information through organisations and the way in which information interacts with individual's belief structures to enable defence planner to understand the possible outcomes of an information operation mission.

To accurately model the challenges of peacekeeping operations will require the development of HBR models of civilian populations and their likely behaviour. In particular, models will need to be developed which incorporate cultural beliefs and attitudes towards other ethnic groups and which predict how civilian populations respond to local conflict. For example, it would be very useful to NATO planners to know how likely a population is to leave their home area when a conflict breaks out and under what conditions they might return.

Furthermore, NATO staffs currently lack tools to analyse the process of achieving political consensus among NATO countries and to estimate the time required by the countries to make to a decision regarding a specific course of action. This lack of tools limits the staff's ability to make realistic or achievable recommendations for proposed courses of action to NATO. The development of sophisticated models of human and organisational decision-making behaviour to address these shortfalls would directly improve the NATO staff's ability to propose acceptable course of action, to anticipate how much time is required to achieve political consensus, and to produce better estimates as to the time require to begin and execute a mission.

In addition, there is a serious lack of models capable of analysing the conduct of joint operations. With respect to HBR, the development of such model should include cultural components or parameters to enable defence planners to better understand cultural difference as they related to command and control and mission planning and execution. In particular, defence planners could use models for peacekeeping operations, which establish the attitudes, beliefs and relationships between different participating entities or organisations and establish the events and /or criteria that could cause a change in relationship between bodies.

Finally, and most important, Defence Planners have limited in modelling support to forecast possible future security requirements. Models are needed that can predict the political changes in the countries around NATO's periphery. Key issues include:

- What types of governments are likely to become established both in the countries that made up the former Eastern Block and the African and Middle Eastern states (e.g., communist, Islamic, neo-feudal [now based upon business holdings rather than land]);
- What will be the relationships of these countries to NATO;
- What types of threats (if any) will they pose for NATO (e.g., cyber warfare; Missile launched WMD; conventional terrorism); and
- What will be the countries economic status and orientation?

Defence Planning requires a range of new models to include:

- Geopolitical models which enable analysis of the possible evolutionary paths that a country may follow;
- Organisational models of non-government organisations and other entities (e.g., the United Nations); and
- Command and Control models, which enable the analysis of systems that incorporate non-traditional allies and interfaces to other organisational entities.

2.3 Acquisition

New systems are usually acquired to counter a perceived threat. The perception of a new threat by the requirements community typically leads to the generation of a mission need statement and then to a series of analytic studies that attempt to determine the best way to counter the threat. Modelling and simulation are used extensively to evaluate mission needs and requirements, trade-off alternative approaches to countering a threat, and to evaluate the system developed to meet the threat. HBR plays a major role in acquisition, primarily through the support it provides to these simulation-based studies.

In the early phases of system acquisition, studies are conducted to determine the best way to address an emerging threat. Often a change in doctrine, tactics, or operational concepts will be sufficient to overcome a threat. HBR is required to support this process by providing realistic models of decision-making, actor, team, group and organisational behaviour. To the extent that one can improve the HBR models, one will improve the subsequent analysis.

Modelling and simulation is also used to evaluate *alternative* approaches and alternative designs. Modelling and simulation plays an especially important role here because design decisions made at this point account for the vast majority of systems life-cycle costs. Consequently, it is important to thoroughly evaluate design options in the most realistic environment possible.

To adequately address the human's role in weapon system design and to establish and validate the system's operational concept a Human System Integration concept must be established [1] and human-in-the-loop studies must be conducted. These studies are expensive, because they require breadboard or prototype equipment, and they significantly add to the development time for a new a system.

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[1] See NATO DRG report on Human Systems Integration (Panel 8 RSG 21)

Furthermore, HBR representations are urgently needed that can be integrated into computer-aided design (CAD) systems. Such models could be used to evaluate the ergonomics and human factors of a design and as a consequence, significantly reduce the development time while simultaneously improving overall system performance. Only HBR models currently exist, which can be used to evaluate anthropometrics (form and fit) aspects of a design. Therefore, the major challenge facing the HBR community is the development of models of cognitive processing which can be used to evaluate cognitive factors such as workload, task allocation between human and machine, and crew sizing and responsibilities. Such models currently exist, but not in a form that can be used in a CAD environment.

Once a design has been selected and prototype (or first article) systems have been built, then modelling and simulation (as well as live test) is used extensively to evaluate the prototype to ensure it meets design specification. Typically, the prototype system is linked or interfaced to a simulation environment where it is repeatedly run through tests. Once again, HBR supports this process by helping to provide both a realistic and cost effective environment in which to evaluate system efficacy.

However, HBR cannot only support the Human Systems Integration but also the whole strategy of military systems acquisition.

This will be explained using the example of SBA.[2] As a result of many factors a sustained and in depth review of the acquisition process has been ongoing for several years leading to the elimination of outdated rules and standards while at the same time revising the process to reflect the realities of the post cold war environment. Today there is a desire to have an acquisition process that is streamlined, enabled by robust collaborative use of simulation technology, integrated across all acquisition phases from concept evaluation, requirements definition, development, manufacture, fielding, to life cycle support and finally disposal. The objective of such a broad thrust is to reduce the time, resources and risk associated with the acquisition process and at the same time increase the quality, military utility and supportability of systems developed and fielded. To carry out such a broad endeavour requires a significant change to the current way the acquisition process is conducted to a new acquisition methodology called Simulation Based Acquisition (SBA). See figure

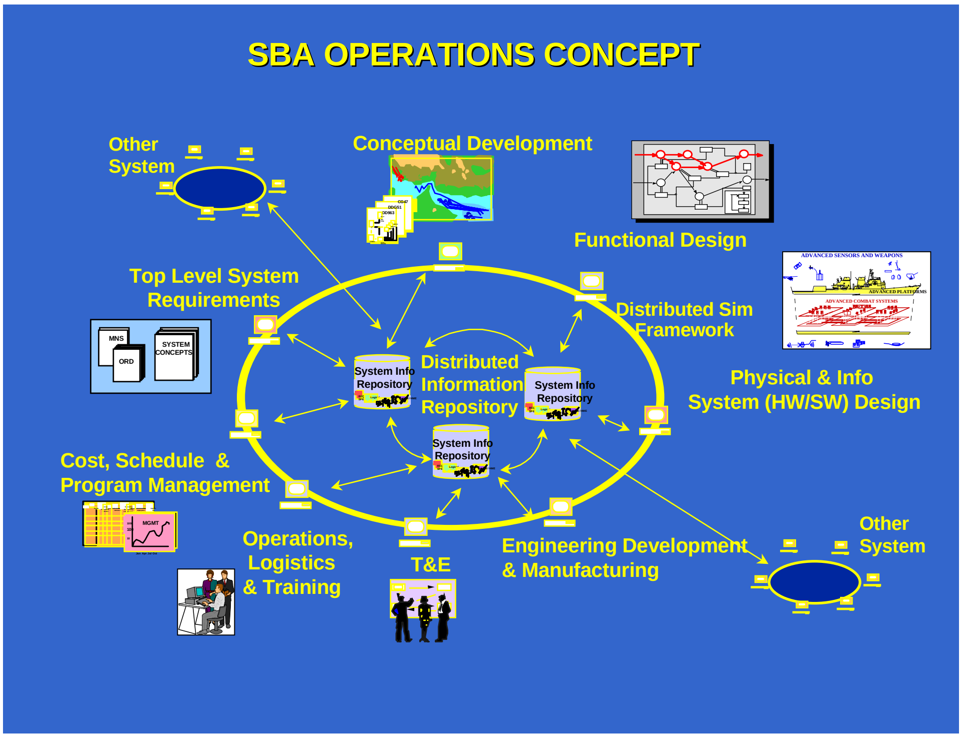

Figure 4: The SBA Operations concept

[2] SBA is the development of a collaborative enterprises that enables interdisciplinary teams to develop new systems in a cost effective manner with a significant reduction in the time it takes to field that system (reduced cycle time).

It is not the purpose here to go into a long dissertation on SBA. However to understand the role HBR plays in SBA it is important to understand a few fundamental requirements necessary for SBA to be efficient and effective. First and foremost is the concept of the collaborative enterprise. The collaborative enterprise *encompasses members* from all phases of the acquisition process including industry. It includes tools that are interoperable across phases of the program, across disciplines, inter program and inter service. An architecture and infrastructure must be available that supports the necessary exchanges of ideas and data, there must be repositories to store and manage data and a digital product description repository and finally the system engineering analysis necessary to make such an enterprise a reality. With its need for data sharing, disclosure, consensus building, expansion of decision making from independent stove piped disciplines to multi discipline cooperation, industry and government as team members, sharing of models and simulations, the collaborative enterprise will become a reality only if the *organisational, cultural and behavioural changes* from how we do business today to SBA occurs. SBA is a challenge to existing culture. HBR models for inclusion in SBA are necessary to support decision-making in the SBA collaborative environment.

The potential benefit of modelling the organisational and cultural change lies in the interest of NATO and multinational collaboration within NATO (e.g. collaboration of the armaments divisions of the nations). It can be expanded to any modelling and simulation effort, when large organisations are going to be restructured, thus prototyping changes, which otherwise would require organisational life experiments.

2.4 Support to Operations

This section starts with a description of the targeted commands and agencies and application area "Support to Operations" regarding the implementation of Human Behaviour Representation (HBR) and ends with requirements and recommendations for the use of HBR in support of this application area and.

2.4.1 Targeted Commands and Agencies

The following levels are targeted for the analysis: NATO Political Structure, e.g. North Atlantic Council, Strategic Commands, e.g. SHAPE and SACLANT, Regional Commands, e.g. AFNORTH, Joint Sub-Regional Commands, e.g. JCCENT, Component Commands, e.g. AIRNORTH, Multi-National Forces, e.g. AMF(L), International Organizations (IO), e.g. UN and OSCE, Non-Governmental Organizations (NGO) e.g. Red Cross, Private Voluntary Organizations (PVO) e.g. Doctors w/o borders. This is a full list of target audience in representing human behaviour in simulation models. In the following section the various application areas will be reviewed.

2.4.2 Description of Application Areas

The integration of simulation with C3I systems and the use of simulation in operations will help decision making in operational situations. Human Behaviour Representation is an essential part in such a system to provide support in situational awareness and course of action generation. The commander will be able to make decision at a faster pace with the benefit of HBR tools.

For different aspects of operations and mission type that is being conducted, there is a requirement for different HBRs. The following aspects of operations and types of missions were considered:

Aspects of operations:

- Contingency Planning (development and assessment of OPLANs.)
- Situation assessment (assessment of threat, own forces, environment, etc)
- Deployment Planning (force generation, movement and deployment)
- Sustainment and Logistics planning (Forces and supplies)
- Rehearsal (Dry run of specific mission)

- Current Operations (real-time monitoring and re-planning, decision making support to commanding, controlling and managing of operations)

Mission types:

- NATO Article 5 Missions (Defence of NATO territory)
- Crisis Response Operations (CRO)
  - Peace Support Operations (PSO)
    - Peace Keeping (PK)
    - Peace Enforcing (PE)
    - Conflict Prevention (CP)
    - Peace Making (PM)
    - Peace Building (PB)
    - Humanitarian Operations (HO)
- Other Security Interests (OSI)

2.4.3 Examples

Rehearsal for Article 5 operation determined to be one of the highest priority requirements for implementation of HBR. In Article 5 scenario it would be very advantageous for NATO commands to rehearse its missions in a tailored simulated environment. The various elements of such a simulation are composed of: opposing side/factions. political and military leadership, Political constituency, subordinate forces and terrorists.

Another aspect that needs to be considered are the friendly forces, composed of higher, lower and lateral commands, political leadership and the constituency. Finally, other participants such as refugees, NGOs, PVOs, IOs, neutral countries and media need to be included. In addition the following functions has to be represented: combat forces, combat support and combat service support as well as C3I.

Current operations are also determined to be a high priority requirement for simulation support and implementation of HBR. In current operations higher, lower and lateral command levels needs to be modelled. The other elements of opposing side and factions, friendly forces, other participants and representation of combat units and related C3I are the same as above example.

Situation assessment is another high priority operation to be considered for HBR implementation. The elements that may be represented are: Data collection, analysis and fusion, evaluation and distribution of information on opposing, and friendly forces. The environment needs to be represented as well. In certain situations there is a need to raise alerts and to manage C3I interactions.

2.4.4 Conclusions and Recommendations

In the application area of support to operations contingency planning, situation assessment, rehearsal and current operations are of high priority for Article 5 and Peace Enforcement missions. Deployment planning and sustainment and logistic planning are of high priority as well for Article 5 operations.

The two areas of high priority which are analysed in paragraph 1.3.5 regarding the underlying components concerning the needed functionality and consequential requirements are stated for each area below.

Current Operations Article 5 Missions

The following assumptions were made regarding the nature of Current Operations in future Article 5 Missions:

- The pace of decision making in Article 5 Missions must be changed dramatically in the future in order to conduct operations before the opposing side is able to react in an ordered way ("fight within the enemy decision cycle").
- Current Operations as basic function will change in this respect from only monitoring to performing tasks that are at the moment handled within Contingency Planning (e.g. re-planning).
- The amount of information and the availability in real-time will increase dramatically.
- Distribution and execution of orders will be much faster to take advantage of a faster decision making.
- The size of staff and forces will be reduced.
- Decision support is needed from the highest military level down to platoon level.

In this context, the following functions should be supported by HBR in Current Operations for future Article 5 Missions:

- Real time option generation to support decision-making.
- Rehearsal (of generated options) using state of the art simulation technology with HBR to get an insight in possible courses of actions.
- Rapid Analysis (of rehearsal results) to support the selection of a course of action.
- From this, the following consequential requirements are found:
- The integration of simulation model and HBR in the operational environment (C4I) is essential.
- The interoperability of national systems plays a major role in conducting combined (multinational) operations.
- The mutual understanding of the planning process at all command levels is necessary.

Current Operations Crisis Response Operations Peace Enforcement Missions

The following assumptions are made regarding the nature of Current Operations in future Crisis Response Operations Peace Enforcement Missions.

- These missions have an increased political dimension.
- There are different concepts of employment, allocation of assets to non-military priority tasks and objectives.
- The objectives are different and more ambiguous in comparison to Article 5 Missions.
- The pace of the decision making process will be rapid.
- At the start of such a mission establishment of the information base is necessary. At this time some basic information may be missing.

- The information (amount and availability) in real-time will increase dramatically (after establishment of the information base).

- The distribution and execution of orders will be also much faster in order to get the maximum advantage of this layout.

- The size of the staff and the forces will be reduced.

- Other nations than NATO nations may be part of the force (Non NATO Troop Contributing Nations NNTCN).

- Training Level, C2 Culture, Procedures, Tactics and Doctrines, Hardware might differ from NATO.

- The engagement area might be different from the usual environment (Terrain, Weather, etc.) in the old scenario.

- Decision Support is needed from the highest military level down to platoon level.

In this context the following functions should be supported by HBR in Current Operations for future Non Article 5 Major Conflict Missions:

- Real time option generation to support decision making including the following features:

    - Explanation capability (the system is not a black box and can explain its findings to the user to get a better acceptance)

    - Distributed Co-operative Planning: All echelons of decision making participate in developing a satisfactory solution in parallel. Complete coherent plan could be generated and synchronised (future systems should support this to enable users to plan in a distributed environment as well as to support HBR to doing so)

- Quick Rehearsal (of generated options) using state of the art simulation technology with HBR to get an insight in possible courses of actions based on the own planning.

- Rapid Analysis (of quick rehearsal results) to support the selection of a course of action.

- From this, the following consequential requirements are found:

- Applicable systems must be rapidly adaptable (learning) regarding the used rules and doctrine.

- The integration in the operational environment (C3I) is essential.

- Interoperability between national systems must be rapidly attained. Because of changing coalitions between nations for this type of mission a requirement for perpetual interoperability between all nations is not realistic.

- The operational procedures have to be adapted to new capabilities gained by HBR (e.g. co-operative planning) and must be trained.

- A mutual understanding of the planning process and the doctrines is necessary. This requires rapid training.

3 Summary of Importance of HBR

3.1 Instruction and training

The goal of instruction and training is to learn new skills and improve specific skills in individuals and teams. In order to support these tasks, it is necessary to develop a model of the subject of the instruction and training (the trainee or group), a model of the instructor and models of the inanimate systems, other human or human-operated platforms that the trainee(s) interact with. The model of the instructor includes evaluation or performance measurement models and models of the various strategies that can be applied to achieve the knowledge transfer objectives. All these models are required for any form of instruction and training. In order to automate these models, they need to be made explicit and it is necessary to develop a suitable framework for human behaviour representation.

Given the growing need to provide effective training, the limited resources available to achieve the knowledge transfer objectives and the increasing complexity of military tasks, the need for automated formal representations of human behaviour is becoming pressing. The availability of the various models described above is essential to support the concept of providing instruction and training for individuals and for teams on an any time, anywhere, on demand basis.

It will also allow the same training standard to be achieved in less time through a better evaluation and feedback capability and through the application of more diverse scenarios.

An improved level of training will also benefit the effectiveness of live training since individuals and teams, trained in simulated environments, will start with an increased skill level. Considerable associated side benefits are the reduced impact on the environment and the increased effectiveness of deploying costly resources. Live exercises will actually become more cost-effective because richer scenario's containing more elements of the environment can be addressed in terms of personnel, artificial and natural components.

The availability of an automated instruction and training environment that includes effective models of the trainee(s), the instructor and the elements of the real world that they interact with will allow continuous training to take place. It would provide every individual and team performing a military task to benefit from a virtual instructor that is continuously monitoring performance and that can provide a just-in-time rehearsal capability.

An effective instructional environment with consistent performance measurement could contribute to the selection and retention of suitable military personnel. Indeed explicit models of human behaviour for specific functions constitute a consistent reference for the selection of personnel that are capable of matching the model's characteristics. As discussed in para 3.2.1, developing good models of human behaviour is critical in achieving this objective and may be of considerable benefit to many NATO nation's armed forces where this problem is widely encountered. It may also contribute to the retention of personnel by providing a more varied and challenging training environment.

3.2 Exercises

Exercises are aimed at maintaining and applying acquired skills. They also serve to generalise knowledge and increase the ability of individuals and teams to select and apply suitable knowledge. Exercises are key to the development of knowledge concerning the application of skills, also referred to as meta-knowledge. They typically require substantial interaction with other teams and the deployment of large numbers of personnel acting as exercise facilitators in the form of directing and response cell staff. In exercises, the emphasis shifts from instruction and training to a form of peer-level coaching. The availability of automated representations of the behaviour of the individuals and teams that the exercising personnel interact with, will allow exercise settings to be composed in a more flexible, modular manner. It will also allow the environment to behave overall in a more consistent manner by removing biases due to level of training and experience of augmentation personnel. Given that the representations have been developed for interoperability and scalability, variable levels of granularity could be mixed to provide the appropriate level of information during the exercises. This is a critical aspect in providing effective interfaces between the exercising environment and the C3I systems used by the exercising staffs.

The consistent behaviour of automated representations and their ability to record actions and information flow will improve the ability to provide feedback resulting in an improved capability for after-action review.

Finally, automated representations of human behaviour will result in a reduction in staffing levels for response cell, other forces and directing staff functions. It will also allow the environment to be used for other purposes e.g. acquisition and decision support. It must also be mentioned that a simulated environment containing these representations of human behaviour will enable the exercising of situations that cannot be created in a live exercising environment.

HBR is a critical enabling component for many NATO activities. In fact, the lack of adequate HBR has been described as a serious limiting factor for many of the types of simulation studies that NATO wants to conduct (NATO M&S Master Plan reference goes here). NATO requirements are changing. NATO is being asked to conduct many new and challenging operations. These new changing missions and threats require advanced modelling capabilities in several areas:

- NATO needs better models of individuals. Such models are needed to improve the quality of instruction, training, and exercises, ensuring that all trainees receive the highest quality instruction at a minimum cost.

- NATO needs better models of organisations and organisational behaviour. Such models are needed to investigate alternative command and control structures that would better support CRO missions such as peace keeping and humanitarian relief. Further, such models would support studies on information warfare and operations.

- NATO needs new classes of models to analyse geopolitical change. Such models are needed to analyse future NATO force and mission requirements.

Advanced HBR models are needed of individual and organisations at multiple levels of resolution, or fidelity. High fidelity models are needed for team training and information warfare analysis, for example. Lower fidelity models are needed for system acquisition analysis, for example. The need for models will most likely exceed NATO countries capability to build models. The challenge is to define a research program that maximises the return on investment so that the maximum number of needs can be addressed.

The return on investment from investing in HBR research is likely to be quite significant. HBR research is already generating new types of applications, spin-offs, to include the automation of tasks normally executed by human controllers in response cells (in command post exercises) and the development of intelligent interfaces that enhance situational awareness by continuously monitoring and fusing information from C2 systems.

4 References

Dompke, U., Scheckeler, K., Final Report on Long Term Scientific Study (LTSS/SAS-017) on Human Behaviour Representation (HBR) Technology, RTO-TR-047, AC/323(SAS-017)TP/25, Brussels, 2001

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The Increasing Need for the Representation of Decision Making and Human Behaviour in Simulations Used for Computer Assisted Exercises in NATO

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Summary

In computer assisted exercises aimed at staffs and commanders operating in NATO headquarters, simulation models are used by response cell personnel to represent the behaviour of the forces that they are commanding. Exercise directing staff and personnel managing other forces involved in the exercise interact with the simulations to complete the representation of the behaviour of the world that is relevant for the achievement of the exercise objectives. Hence the quality of the exercise depends heavily on the quality of the personnel that interact with the simulation environment. Their ability to understand and interpret the intentions of the exercising staff and to provide them with relevant information through their regular command and control information systems is critical to the success of an exercise. Due to the increasing number of different aspects of the real world and associated scenarios that need to be exercised, the range of activities represented in the simulation models and the breadth and depth of knowledge of the personnel who operate them must grow and adapt rapidly. However the time to develop new simulation models and to adapt existing ones to new requirements has not been reduced considerably in the last decade. The availability of highly qualified personnel to interact with simulations, represent subordinate commanders and staffs, intelligent opponents and interested third parties is limited in both numbers and time. So although considerable improvements have been made in the preparation of the simulation environments to meet exercise objectives, most computer assisted exercises suffer from poorly trained response cell and other forces personnel. Also the reduction in the size of forces, the greater effect and effectiveness of weapons and the importance of inflicted damage causes individual tactical decisions and actions to have a major impact on the battlefield and the exercise. Therefore, the ability to incorporate automated representations of autonomous planning and decision making and real time conduct of operations will be critical in overcoming these problems. Equally important will be the development of intelligent information presentation entities capable of interfacing with small numbers of simulation operators and with real world command and control information systems. It appears that progress in the representation of computer generated forces and human behaviour modelling may allow these capabilities to be developed. The ability to enable them to go beyond reproducing known behaviour according to established patterns and display some form of creative thinking and unanticipated behaviour will be essential in making them effective for any length of time.

1 Current Practice of CAX in NATO

"A computer assisted exercise (CAX) is a Command Post Exercise in which computer-based simulation models are used to place commanders, staffs and their command and control systems in an operationally realistic environment in order to perform decision-making, practice staff procedures and co-ordinate between headquarters." *(ACE CAX Planners Course*)

Paper presented at the RTO SAS Lecture Series on "Simulation of and for Military Decision Making", held in Rome, Italy, 15-16 October 2001; Stockholm, Sweden, 18-19 October 2001; Virginia, USA, 23-25 October 2001; The Hague, The Netherlands, 10-11 December 2002, and published in RTO-EN-017.

A number of groups of persons complement the simulation environments in providing a realistic and challenging environment for the exercising staffs. They include:

(1) Response cells, which constitute the interface between the exercising staff and the simulation environment. They represent all subordinate units, perform the corresponding decision making process, interact with simulated entities and provide information feedback to the staffs. A growing number of automated interfaces between simulations and NATO command and control information systems enable response cells to provide data in the format that staffs are familiar with.

(2) A white cell, which represents other elements that provide information to the exercising, staff e.g. media or political leadership.

(3) One or many opposing or other forces cells which manage other active and simulated entities. They develop plans and execute them in order to meet the exercise objectives.

(4) A directing staff which interacts with all exercise components including the exercising staffs to monitor the progress of the exercise.

(5) An analysis team collects data during the preparation and conduct of the exercises to provide feedback on the achievement of the exercise aims and objectives.

Two distinct levels of decision making are the typical focus of computer assisted exercises in a NATO context:

(1) the operational level of decision making where the most important problem areas that require resolution center around the assessment of threat, the specification of the resources required to achieve the assigned objective within the assessed threat environment and the general allocation of joint and combined resources to specific tactical tasks. The time frame of events that is relevant to the decision making process at these levels is expressed in weeks and days rather than in minutes.

(2) the level of decision making that constitutes the transition between the operational and the highest level of tactical decision making. At this level, single service considerations start to become of overriding influence. They are still focused at the usage of large structured groups of persons and equipment and consider the environment at a macro-level. The time frame that this level of decision making considers is shorter than the previous level but is still expressed in days and hours rather than minutes.

The decision making process is a combination of qualitative assessments and quantitative aggregate data processing. The associated information generated by either the headquarters’ subordinates or other sources is both structured and unstructured. Typically the higher the level of decision making, the smaller the quantity of structured information. Hence the greater need for response cells to understand the intent of the exercising staffs and their need for assessments rather than facts.

The simulations that are used to support CAXes in NATO have been selected based on their functionality and their level of granularity. Indeed, interaction with the simulations is typically carried out by the response cells and other forces cells at the level of the simulated entity. Reporting from the simulations is also typically at the simulated entity level. Due to the nature of NATO exercises, the simulated entities have always been relatively aggregated elements e.g. army battalions, flights of aircraft or naval task groups.

2 Changing Requirements

The change in NATO's security environment that has taken place since 1989 and the new missions that NATO has been called on to perform, have had a considerable impact on the types of simulation environments required to support the growing variety of exercise objectives.

Specifically due to the types of operations that are currently undertaken by NATO in a peace support context, there is a growing need to track the activities of individual entities as well as structured groups of entities. Indeed, the size of the forces involved are relatively limited. In these operations, the decisions that are made by individual entities and at every level of organization are carrying an increasing degree of importance and therefore of interest to senior decision makers. The growing capability of small forces and the effectiveness of single weapon systems contribute further to this trend. Both the expected and unexpected effects of weapon employment need to be represented in exercise simulation environments to provide a representative information flow to the exercising staffs and commanders.

Another marked change in requirements is the collaboration with civilian organizations either governmental or private in nature. Their activities need to be represented as well as their interaction with local populations.

All the above elements require simulation environments for CAXes to include a wider variety of entities with behaviours that have not been studied in this field in the past. In addition the interactions between the traditionally simulated entities in CAX-driving simulations and these new entities are not well structured and understood. Overall, there is a tendency to demand a growing level of granularity in order to understand the behaviour of the entire set of entities.

An aspect that complicates the development of simulation environments that meet these changing requirements is the increased usage in NATO of direct interfaces between the simulations and the command and control information systems (CCIS) used by the exercising staffs. These interfaces include such capabilities as automated report generation in a format that can be processed automatically by a CCIS, the provision of air and maritime track data but also the processing of structured order sets produced by the exercising staffs. The usage of these interfaces limits the ability of the exercise control organisation to influence the course of the simulated events in any intrusive manner. Hence control needs to be executed with greater insight. Better fidelity of entity behaviours is expected due to this increased visibility. The ability to explain the occurrence of certain unexpected and apparently illogical events is critical in achieving confidence in the simulation environment used to support a CAX. Conversely, exercising staffs need to take sufficient care in the development of plans, which are transmitted as structured tasks to automated entities. Usually the simulated entities have limited ability to validate the tasking and may therefore execute errors in a perfect manner rather than provide some form of feedback requesting confirmation of the tasking.

3 Solutions and Constraints

In order to respond to the change in requirements described in the previous section, a number of different approaches have been proposed and applied in the NATO context. Most notably, a resurgence of purely scripted exercises or largely scripted CAXes has been observed. The traditional problem, associated with scripted exercises, of providing consistent responses over time to the exercising staffs and commanders with the required level of detail has been re-discovered. The complexity of managing the interactions between a wide variety of entities and of conveying the perceptions of opposing or non-aligned entities cannot be resolved in this manner. Hence exercise effectiveness has been limited and this approach can only be applied to exercises that focus on a very limited set of objectives and that aim to exercise a limited group of people. The facets associated with a combined joint operation in a multi-national and multi-party environment cannot be simulated using this approach.

Other approaches are based on simulation technology. They can be classed in the following categories:

(1) the introduction of greater granularity in existing and proven aggregate simulations.

(2) the search for simulations that have a greater degree of granularity whilst maintaining a wide spectrum of functions.

(3) the proposed connection between aggregate and detailed simulations or between complementary detailed simulations.

(4) the development of new simulations.

All these approaches focus on achieving the required detailed level of granularity in the simulated entities. They also assume that interaction with the simulation(s) for order input and information retrieval, must take place at this level of detail. Therefore, they require the utilisation of large amounts of augmentation personnel to bridge the gap between simulation and exercising staffs. However the number of available augmentees is decreasing. Due to the rise in numbers of exercises to meet the larger set of operational tasks, they are also in greater demand. Consistent reductions in exercise budgets further limit the deployment of augmentation personnel. Even in the case that numbers of people and funds were available, it has been noted that there is great variance in the skill level of the augmentation personnel and that this variance detracts significantly from the achievement of exercise objectives.

Another element that needs to be taken into account, is the considerable increase in exercise preparation time lines due to the more complex simulation data base development process. Indeed more creative and lateral thinking is needed when applying existing simulations and more development effort is required when building data bases for several simulations and ensuring their consistency. The uncertainty concerning the resulting behaviour of the simulations does not contribute to a smooth and consistent process.

From a technical perspective, it must also be noted that the limited resources available to develop and evolve simulation environments prevent the proliferation of new simulations based on new requirements.

Therefore we must conclude that without a complementary approach to reduce the complexity and detail of the interaction with the simulation environments that are used in CAXes and a focus on the exercise preparation process also, these approaches cannot be applied in cost-effective manner.

4 The Need for Human Behaviour Representation

It becomes apparent from the previous section that the problem of simulating with greater detail while interacting at an aggregate level needs to be resolved in a structural manner. Therefore, it is necessary to augment the description of simulated entities with more complex behavioural representations in particular in the areas of decision making and information processing.

In addition, there is a requirement for a more formal meta-model of the simulated entities to enable their proper configuration and their associated entities during the exercise preparation process. In the context of this paper, we will limit the discussion to the entities that are being simulated.

The issue of the validation of simulation results also requires an explicit representation of the behavioural process of the simulated entities. Not only the actions of entities but their rationale needs to be reproducible and available for inspection. Hence the following characteristics of an entity need to be described explicitly:

(1) the capability to maintain a perception of the state of the world and how it pursues this objective,

(2) the manner with which it assesses potential changes in the state of the world and its ability to apply this process,

(3) the ability to receive and interpret taskings,

(4) the manner with which taskings are interpreted,

(5) the ability to communicate with other entities that are capable of providing useful information and that in turn may need data.

Obviously when instantiated in the simulation execution some level of variance needs to be introduced to ensure a non-stereotypical and reasonably unpredictable behaviour. These characteristics can be used to describe individual and groups of humans.

In addition the process that entities apply to adapt and change their behaviour to achieve certain goals, needs to be defined. Goals could be expressed in terms of intrinsic goals e.g. survival, or externally driven goals e.g. tasking by interacting personnel or other entities. Changes in behaviour could be temporary or become permanent according to some explicitly described process.

Due to the considerable change in requirements described in the previous section, the spectrum of human behaviour that needs to be represented is very broad. It includes:

(1) military staffs and decision makers representing the subordinates of the exercising staffs and commanders as well as the crews operating vehicles or pilots flying aircraft and all the intermediate levels of decision making and information processing

(2) Non-Governmental and Private Volunteer Organisations as groups and as individuals

(3) civilian population groups and key individuals

(4) other military force structures described in a similar manner as the own forces

(5) national agencies either political and military, capable of providing additional information or guidance

(6) commercial and private groups or companies that can provide resources e.g. transportation assets or relevant information e.g. news, terrain or weather data.

The diverse nature of the entities listed above and the many factors that can influence their behaviour, indicates that the task of modelling them will not be an easy one. However it is essential to start introducing corresponding behavioural models in our simulation environments to provide a sufficiently complete representation of the environment in which senior military decision makers and their staffs will be placed in most future operations. The introduction of automated behaviour is critical in providing a consistent quality of training and exercising and in making it affordable.

In addition to modelling the ability of these entities to gather data, to assess situations, to evaluate courses of action, to decide on a preferred path, to communicate it and to execute it, close attention must be given to the fact that these behaviours will change over time. The model development cycle must therefore be shorter than the actual behavioural adaptation cycle. Ensuring an adaptive design to the modelling of human behaviour will be key to its continued success and utility in an exercising environment designed for high-level staff and decision makers.

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Human Behavior Representation – Recent Developments

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ABSTRACT

Until recently, the command and control processes and especially the decision process were - if at all - hard-coded in the closed combat simulation models. Although in other application areas expert systems and rule systems as well as neural nets were used to find solutions to similar problems, in the closed combat community these approaches are still not used sufficiently.

The problem with hard-coded decisions is always, that they are evaluated only for a special environment. Being transferred to another environment the decision model is seldom capable to meet the new requirements. Self-optimization and the skill to adapt to new situations are nowadays more often required by such systems.

This lecture introduces adjustable rule sets and neural networks as alternatives to generate orders in a given situation. The results and the possibilities for further improvement and evaluation of the results are given. In addition, some technical aspects of coupling the results in form of CGF federates with legacy systems and the challenge of structural variances are copied.

Further actual developments in the modeling of Human Behavior Representation come from Germany, where a new approach trying to catch the insight from latest psychology findings as well as modern agent technology are merged to a new solution of the well-known problems.

1 Introduction

This paper is divided into two parts.

In the first part, the recent findings regarding technology itself are introduced and compared. The technologies being introduced are neural networks and adjustable rule sets, already known from applications of expert systems.

The second part describes the actual findings of German study conducted on behalf of the German Ministry of Defense, Joint Staff. These works closely tied to respective NATO RTO activities as Germany has the leading for the ongoing LTSS on Human Behavior Representation, also being a topic of the underlying lecture series.

For additional information, respective points of contact are given at the end of this paper.

2 Technologies

Two techniques have been used to present knowledge that can be used to generate situation adequate orders for simulated units: rule systems of expert systems and neural nets. Both are typical representations of intelligent systems, however, both have advantages and disadvantages when choosing what is the right technique for an order generating instance within a closed combat simulation.

Paper presented at the RTO SAS Lecture Series on "Simulation of and for Military Decision Making", held in Rome, Italy, 15-16 October 2001; Stockholm, Sweden, 18-19 October 2001; Virginia, USA, 23-25 October 2001; The Hague, The Netherlands, 10-11 December 2002, and published in RTO-EN-017.

The basic means have been developed during the dissertation [Tolk 1995] at the University of the Federal Armed Forces of Germany, Munich, and have been successfully applied within several research and industry projects, examples given in [Dompke & Tolk 1999, Tolk 1999a, Dompke 1999].

In this chapter, the terms adjustable rule sets and neural nets are defined in a way to understand the differences and potentials of both techniques. For exact definitions references to the respective literature are given.

This chapter is an extract from the article [Tolk 1999b], where more details and additional technical aspects are given.

2.1 Adjustable Rule Sets

Adjustable Rule Sets can be defined as a quadruple of input Parameters (x1, ..., xm), steering parameters (p1, ..., pj), a set of parametric rules (R1( ), ..., Ri( )), and output parameters (y1, ..., yn).

Dependent on the steering parameters the input parameters are matched to the output parameters by the rules within the rule set. Figure 1 shows this.

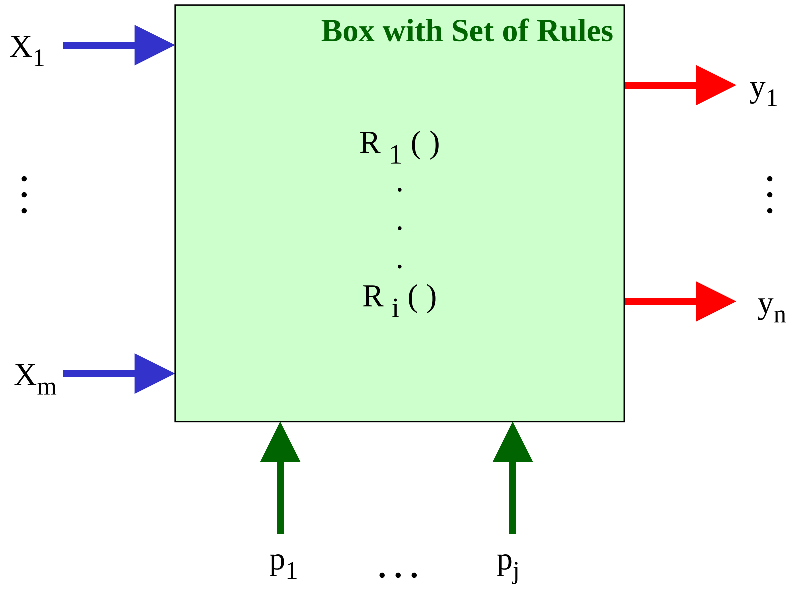


Figure 1: Adjustable Rule Sets

The internal rules can be seen as mathematical functions being as simple as possible or complex as necessary. They can range from simple addition algorithms over optimization algorithms to complex simulation functions being used for trend analyses on which e.g. the decision of other rules can be based on.

However, the rule set is limited and well defined. The steering parameters can be used as parameters within the functions being used by the rules, as parameters to choose which rules or sub-rule sets can be selected and so on. Therefore, the rules can be very flexible adapted by the steering parameters as long as the interior structure has been chosen adequate when building the adjustable rule set.

A more formal definition can be found in [Tolk 1995].

2.2 Neural Nets

Neural nets can be seen as a new way of computing by composing functions out of very easy and simple basic functions. These functions can be interconnected by their input and output parameters in a weighted manner similar to the neuron connections in the human brain.

Each neuron can be defined by its input parameters weighted by a synaptic value and the activity function transforming the synaptic sum to one output parameter. Connecting the output parameter with the input parameters of other neurons results in a neural net.

In this sense, a neural net can be defined as a triple of input Parameters (x1, ..., xm), synaptic weights (w1, ..., wj) that implicitly defines the topology of the net, and output parameters (y1, ..., yn).

Dependent on the synaptic weights the input parameters are matched to the output parameters, as can be seen in Figure 2.

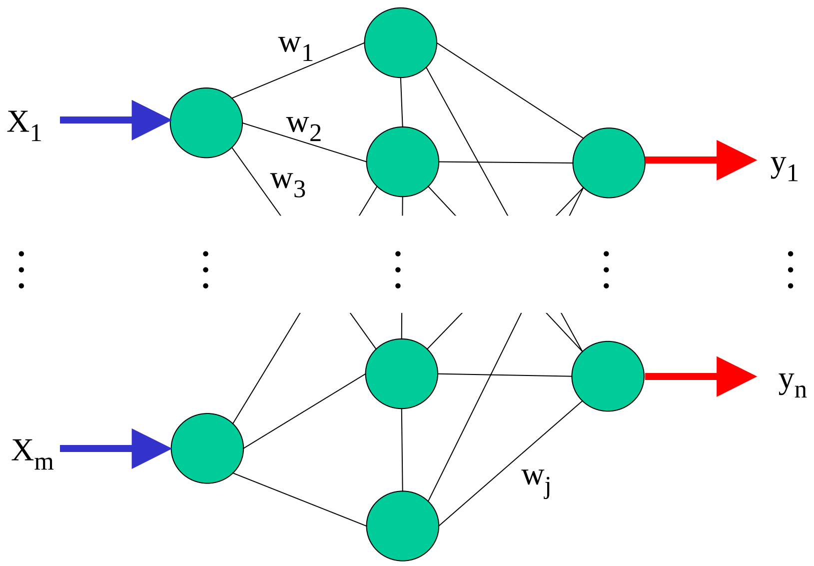


Figure 2: Neural Nets

Normally, the weights are set during the learning phase. When the net is used to match the input values to respective output values, all the information is hidden within the structure of the net and the actual chosen synaptic weights. Therefore, the weights are not steering parameters. However, the net can learn to use input parameters or hidden patterns in the input parameters as implicit steering parameters to be used within the net to decide what the correct output values are in such a case.

A more formal definition can be found in [Masters 1993] and uncountable other publications.

2.3 Comparison of Adjustable Rule Sets and Neural Nets

In general, the technique of adjustable rule sets belongs more to the family of deliberative – i.e. descriptive – CGF solution, whereas neural nets are more likely to be seen as reactive represents of CGF.

In order to compare both techniques, seven areas of interest are evaluated. The importance of each area for fulfilling a given task is the criterion for the decision which techniques can be used for a special purpose.

All seven sections describing each area comprise three parts. The first one describes the objective, the second the aspects of adjustable rules and the third the aspects of neural nets regarding the objective.

Approximation of a Function

The Objective is to approximate an implicit given function to arbitrary accuracy in order to use this function for the decision process.

- Every known function can be programmed as a rule within the adjustable rule set. However, having just an implicit given function assumptions have to be made. It is possible to introduce several alternatives that can be selected by respective steering parameter values.
- Neural nets can approximate every function to arbitrary accuracy, even if the function is subtle or deeply hidden within the patterns of the learning examples [Masters 1993]. No assumption – potentially unnecessary limiting the search area for the solution – has to be made.

Use in Similar Situations

The Objective is to get meaningful results when applying the techniques in areas having only a similar situation that do not match exact learning examples.

- In general, adaptive rule sets use standard rules for standard situations. The main problem is, therefore, to find the most similar standard situation. If a situation is to far away from all introduced standard situations, a new rule has to be created and programmed.
- Due to their ability to generalize a neural net can make a decision in every situation. If a given situation is within the domains of the training examples, the neural net can produce an adequate interpolation between all affected standard or training values. However, even if there is no relevant training data and the situation is completely new, the neural net will make a decision anyhow, without warning the user that the assumptions are not true for a given application.

Possibility of Adaptation

The Objective is to adapt the technique to a new situation with very little effort.

- If the adjustable rule set is flexible enough, i.e. if all necessary inner parameters can be set from outside by steering parameters, the rule set can be adapted to a new situation by choosing the right values for the steering parameters. In [Tolk 1995] this has been done for the rule set of a complex rule system of a closed combat simulation system on Corps/Division level. However, it may be necessary to introduce new rules for unforeseen situations.
- Using the techniques of reinforcement learning, a neural net can be adapted to every new situation. However, this process can be very time consuming. If in addition the net topology is suboptimal or even wrong, it is necessary to rebuild the neural net and to start from the beginning.

Possibility of Optimization

The objective is to optimize the technique in another situation rather than the foreseen one.

- By choosing the right steering parameter values, the behavior of adjustable rule sets can be dramatically improved. However, the number of inner functions and rules limits the solution space being reachable for a given set.
- As every function can be approximated sufficiently, each optimum can be reached. However, as in many cases means of heuristic optimization like genetic algorithms or simulated annealing have to be used, it is not sure that in every case the optimum is really found. In addition, the process can be very time consuming.

Extensibility

The objective is to extend the technique by the user for new situations.

- New rules can be added to the rule set at any time and existing rules can be modified. There are no limitations to this process.
- Extending a neural net means, that in cases the net topology has to be changed, and a new training phase is necessary. All the former work has to be done again. It is not possible for the user to add new information by analytical means.

Explainability

The objective is that a user can understand how a given decision has been made within the means of the underlying technique, i.e., how can the results be explained – at least in the retrospective – for the user?

- A rule set can be well understood due to the inner construction of human readable rules and functions. In addition, explaining components can be used being attached to the respective rules. When using expert systems, the user can be informed about all aspects all the time.
- This is impossible for neural nets. There are no explaining components for this technique. Even the evaluation of the synaptic weights and the topology of the net is of no benefit for the user. Neural nets "have to be believed".

Effort of Construction

The last criterion focuses on the effort that is necessary to build an adjustable rule set or a neural net to generate orders and to be used as a CGF federate within a legacy simulation system.

- Before optimizing an adjustable rule set, as has been done in [Tolk 1995], the rule set has to be created and all rules have to be implemented at first. Although this can happen gradually and in an evolutionary software development process, this can take a tremendous amount of effort. In addition, respective experts are necessary to define the functions from the users point of view. On the other hand, having a given rule set that can be made adjustable by making all respective steering parameters public. Afterwards, genetic algorithms and other heuristic optimization techniques can be used to adapt or optimize the legacy rule set [Tolk 1995].
- In order to build and train a neural net, at least the input and output parameters must be known. In addition, the complexity of the problem must be known in order to define the topology of the net correctly. When choosing the right topology, all benefits of neural nets can be used. However, we are still missing an exact method to define an adequate topology. For non-trivial problems only heuristics can be used.

Summary of Comparison Results

The summarize the findings of this chapters it can be said, that both techniques – adjustable rule sets as well as neural nets – have their justification in different contexts. As a rule of thumb, adjustable rule sets are to be preferred if the Explainability of the results is the main objective, and neural nets are to be preferred if the finding of optimal solution is the main purpose. However, both methods are still in the domain of actual research and development.

2.4 Example of Applying Adjustable Rule Sets and Neural Nets for Optimization

The application shall be exemplified showing the research results having been conducted by the author at the University of the Federal Armed Forces of Germany, Neubiberg/Munich, during he was working on his Ph.D.-Thesis [Tolk 1995].

In 1991, Jim Dewar of RAND Corporation published the work of his team concerning chaos in closed combat system [Dewar et al. 1991]. He introduced a very simple combat model, mainly based on a Lanchester attrition model including reinforcement by reserve. The decision to introduce the respective reserve group was based on two rules. The first rule looked at the actual force ratio, the second at the actual own strength. The battle ends when passing given thresholds for force ratio or remaining strength, i.e., if the force ratio rises over a given value or if the remaining strength falls below a given percentage of the initial strength. The following figure shows the results of parametric variations of the initial strength of red and blue forces.

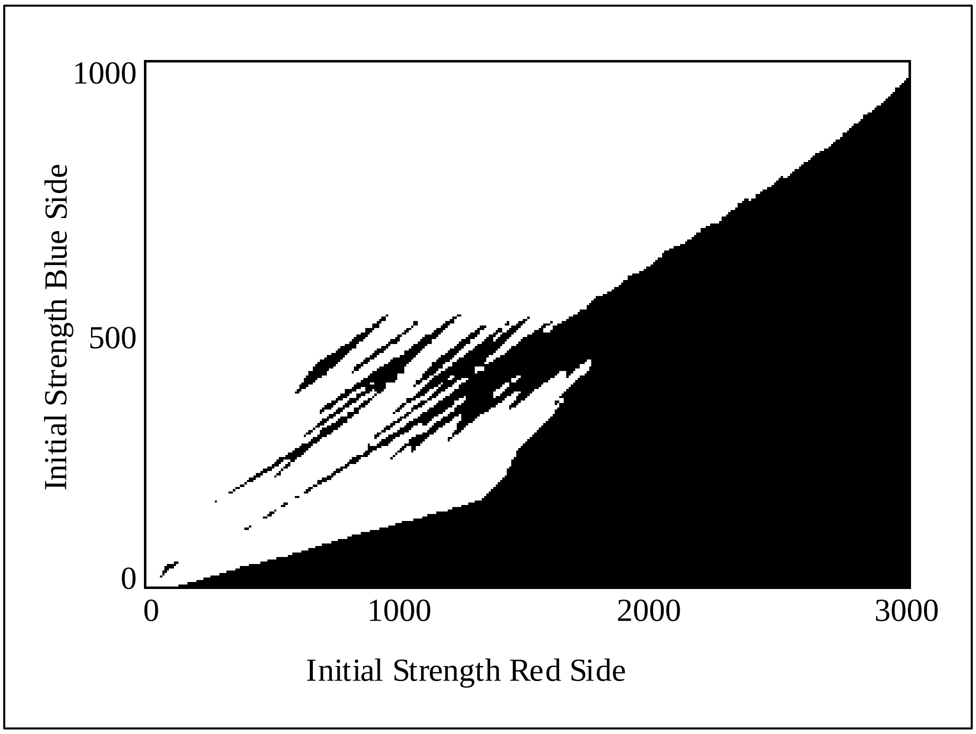
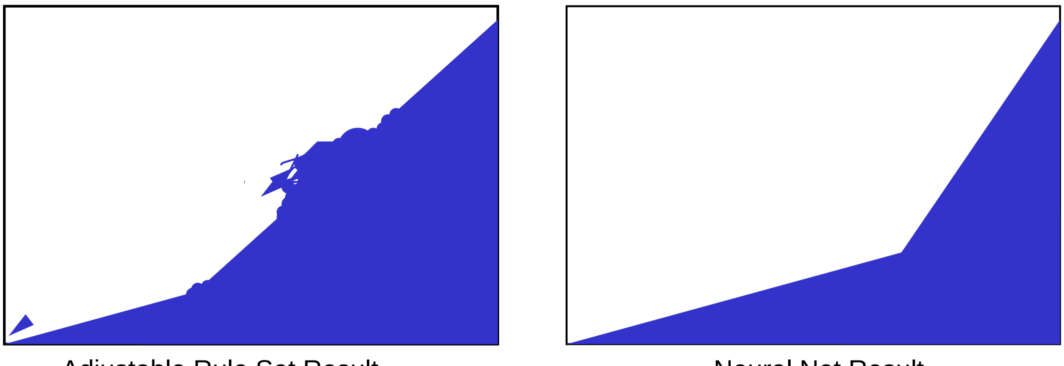


Figure 3: Simulation Results before Optimization [Dewar et al. 1991]

Within [Tolk 1995] it was shown, that the reason for the non-monotonicities was not chaos. The decision rules used were just not situation adequate, thus resulting in structural variances. Such variances do not occur only in closed simulation systems, but also in simulation federations, even when using validated and verified software modules, see [Tolk 1999a].

Using the optimization capabilities of adjustable rule sets as well as neural nets leads to interesting results. To do so, the decision rules were interpreted in the sense of adjustable rules on the one hand side, and on the other hand side, a neural net was trained to engage the reserve based on the actual perceived strengths as well as the initial strength of both sides. The following figure shows the results.



Adjustable Rule Set Result

Neural Net Result

Figure 4: Simulation Results after Optimization

It is obvious that the neural net did the better optimization, however, it took a few days to understand what really happened and what the neural net did learn. On the other hand, the result of the optimized rules still could be improved, but the results could be understood at once without further evaluation.

3 Recent and Actual German Works

This chapter is based on a briefing having been given during the German-American Workshop on Command and Decision Modeling for Military Applications at Ft. Leavenworth, Kansas, by the German project manager for the study on Human Behavior Representation [von Bayer 2000].

The study itself is conducted on behalf of the Joint Staff of the German Ministry of Defense. To reach the study tasks, an interdisciplinary team approach was chosen. The team comprises human behavior experts and psychologists, military experts for command and control, peace support operations, etc., simulation experts and is open to other matter of subject experts in case of need. Beside the program manager Dr. Alexander von Bayer, two outstanding experts belonging to the team should be mentioned also: Prof. Dr. Kluwe from the University of the Federal Armed Forces at Hamburg, Germany, and Prof. Dr. Heineken from the University of Duisburg, Germany. In addition, officers from the MoD as well as from the Office for Exercises and Training are involved.

3.1 Study Tasks and Goals

The study task is to investigate, whether and how models of human behavior are needed for military simulation (analyses, computer assisted exercises, and support to operations) and how simulation technology itself has to be expanded in order to cover human behavior. Additionally to this more conceptual work, a prototypical demonstrator has to be developed. Last but not least the German national study is also used to sponsor the leadership within the respective NATO efforts.

It should be pointed out that the efforts should not lead to just adding a human component to legacy simulation systems, but the simulation of the socio-technical military system (single decision making, group decision process, perception of truth, individual and group behavior, influence of pressure, etc.) itself should undergo a rethinking process. From the NATO activities as well as from respective workshops and symposia it became already clear to the international simulation community, that human behavior representation becomes an application and research domain of its own.

Consequently, different from the well known US study efforts, the German study tries to focus on the answer to the question: What human behavior is relevant in military scenarios and how can this be modeled? In other words, the study and the prototype don't try to model the human being itself but only the relevant human behavior in defined military situations. Starting with the NATO RTO definition: "Human behavior is a purposive reaction of a human being to a meaningful situation!" Germany is trying to define respective scenarios and vignettes to develop the prototype.

It was one of the main goals of the study team not to build up an own private psychology, but to base their efforts on accepted theoretical knowledge. In order to do so, the action regulation theory motivation concept as well as the ideas of natural decision making were evaluated and merged into a new approach being useful to describe real world phenomena, building an adequate theoretical concept, leading to respective mathematical models being able to be formatively validated gradually. One of the first main results is the Action Theory Based Model to be described in a little bit more detail in the following section.

3.2 The Action Theory Based Model

As already has been pointed out, the efforts are concentrated on those elements being directly understood in a military context, thus minimizing the necessary theoretical effort. In addition, model building and validation should go hand in hand whenever possible. Logically, the resulting Action Theory Based Model tries to visualize the inner processes of human behavior connecting given tasks and situations with respective outcomes. The following figure shows a simplifying view, however, the main ideas should become already clear.

Note that again, like in the ideas described earlier in these proceedings within the chapter "Computer Generated Forces - Integration into the Operational Environment", we are using the concept of encapsulated functionality and well defined interfaces. For this black box of a behavior model, the inputs are defined as a given situation and the tasks to be performed, the output are the results. Therefore, an embedding simulation system can be used as a test bed.

Additionally, the steering or calibration parameters are used – the individual/personal characteristics as well as the team/group characteristics – to configure the model behavior like it is done for adjustable rule sets.

Overall, this allows us not only to design and implement behavior models in a modular and configurable manner, but we can also embed them into test beds or into the operational environment later using the integration techniques already described. Note that the interfaces again can be described using the standardized data elements of the NATO Standard Land C2 Information Exchange Data Model.

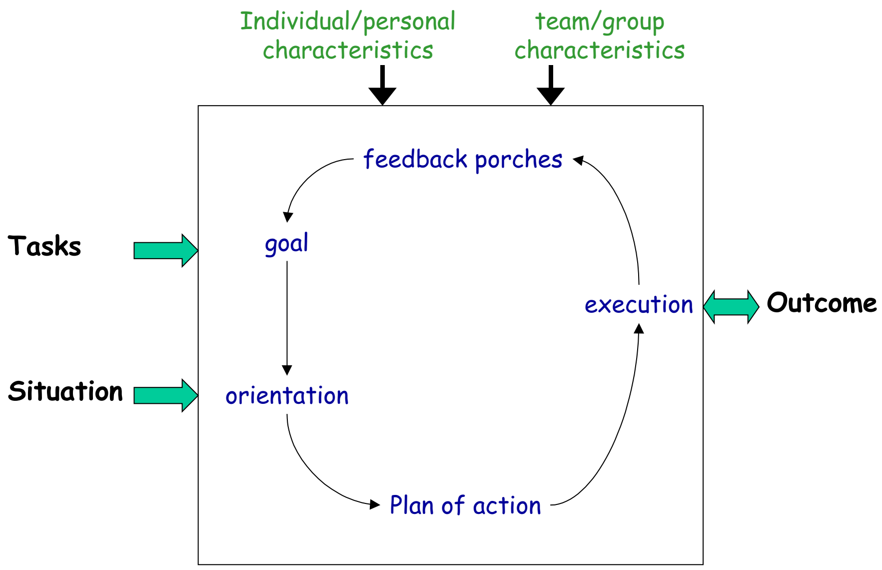


Figure 5: Behavior Process Model

This model allows to integrate and comprise cognitive processes (perception of the situation, recall of knowledge which is relevant to the recognized situation) as well as regulatory processes (causes of intentions, selection of intentions, change of intentions, etc.). Within the Action Theory Based Model therefore

- knowledge is activated and motives are triggered through situational elements
- intention is activated through anticipated goals and
- intention is executed using available (scripted) schemata at hand.

By introducing respective motives and schemata into the model, the parameters now can be set to model respective human behavior in given military situations. Motives themselves represent the human needs making the individual or group acting the way they are. Well-known motives are

- performance motive: accomplish what is ordered
- help motive: help people in need, irrespective of tasks
- might and imposition motive: imposing the own will
- social acceptance motive: doing what is assumed to be perceived to be done by others (or simply to be liked by others)
- personal security motive: personal security first
- aggression motive: wish to destroy and kill (e.g., for revenge or hate)

For the purpose of the study, only three schemata are scripted:

- “How to help” schema: Do whatever can be done to help
- “Task accomplishment” scheme: Task first, don’t deviate
- “How to delegate responsibilities” schema: Let other people decide (manager syndrome – never be in the same room as the decision), avoid responsibility

Motives as well as schemata are different in individual strength, thus being parametrical variables within the model itself.

Without going too much into details it should be mentioned, that this model has to be adapted to the three main behavior domains:

- Human Behavior Representation (behavior of individuals, i.e., prototypical soldiers and civil persons. However, it is not possible to model a real person, e.g., a real politician, to simulate the decision to be expected)
- Organizational Behavior Representation (behavior of organization, e.g., headquarters, command posts, governmental and non-governmental organizations, etc.)
- Mass Behavior Representation (behavior of large groups of people, e.g., demonstrations)

For all three domains, respective schemata – as defined above – can and have to be established. First works already proofed the feasibility of these efforts. In addition, it seems to be worth to think about a “warfighter like” presentation of the motives and schemas in their language and value system to make the results more understandable and easier to accept.

3.3 Application Areas

The German study started with human behavior representation for Computer Assisted Exercises, however, the application area is much larger. Anyhow, for the first steps, leadership training on all command levels with computer generated forces becomes possible. Training of commanders and their staff as “computer aided behavioral training” (e.g., for OOTW), the selection of leaders in realistic scenarios (OOTW assessment centers) etc. are additional features coming i9nto reachable distance (if wanted by the contractors).

4 Summary

To summarize this paper we seem to be on the edge of several breakthroughs. New technology and ongoing revolution in the information technique are leading towards new challenges and chances in the application domain of simulation of and for command and control.

NATO – and especially the Research and Technology Organization – has to step into its place not only to make the findings available to the nations, but also to harmonize and direct the different research efforts.

On the long term, the different domains of defense applications – be it simulation systems, command and control systems, human behavior representation, consultation, etc. – have to grow together, and this should take place under the leading umbrella of NATO.

5 Points of Contact

For further information on the neural network and adjustable rule set approach please contact the author of this paper.

For additional information including reports of progress feel free to contact the project leader:

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Human Behaviour Representation - Relevant Technologies and their Development

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Modelling Human Behaviour (Factors) in Decision Making

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<table>
<tr><th colspan="4">REPORT DOCUMENTATION PAGE</th></tr>
<tr><td>1. Recipient's Reference</td><td>2. Originator's References
RTO-EN-017
AC/323(SAS-032)TP/26</td><td>3. Further Reference
ISBN 92-837-1085-1</td><td>4. Security Classification of Document
UNCLASSIFIED/
UNLIMITED</td></tr>
<tr><td colspan="4">5. Originator Research and Technology Organisation
North Atlantic Treaty Organisation
BP 25, 7 rue Ancelle, F-92201 Neuilly-sur-Seine Cedex, France</td></tr>
<tr><td colspan="4">6. Title
Simulation of and for Military Decision Making</td></tr>
<tr><td colspan="4">7. Presented at/sponsored by
the Studies, Analysis and Simulation Panel (SAS) and the Consultant and Exchange Programme of RTO in support of a Lecture Series presented on 15-16 October 2001 in Rome, Italy, 18-19 October 2001 in Stockholm, Sweden, on 23-25 October 2001 in Virginia, USA and on 10-11 December 2002 in The Hague, The Netherlands.</td></tr>
<tr><td colspan="3">8. Author(s)/Editor(s)
Multiple</td><td>9. Date
June 2003</td></tr>
<tr><td colspan="3">10. Author's/Editor's Address
Multiple</td><td>11. Pages
168 (text)
751 (slides)</td></tr>
<tr><td colspan="4">12. Distribution Statement There are no restrictions on the distribution of this document. Information about the availability of this and other RTO unclassified publications is given on the back cover.</td></tr>
<tr><td colspan="4">13. Keywords/Descriptors
Decision making
Simulation
Command and control
CCIS (Command and Control Information System)
CGF (Computer Generated Forces)
HBR (Human Behaviour Representation)
Military Decision Process
Operations research
Decision support tools
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CAX (Computer Assisted Exercise)
Operational requirements
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Closed simulation systems
Thinking automated opposing forces</td></tr>
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14. Abstract

This Lecture Series gives an overview on the use of M&S of the Military Decision Process in the different application areas of training and exercising, support to operations, analysis and acquisition, and provides a review of the state-of-the-art in the respective areas.

The Military Operational Requirements for CAX systems are the basis for a CAX system architecture that is built on top of services. The coupling of the simulation system with the operational environment in form of the Command and Control Information System (CCIS) is essential. Practical examples and future needs are adduced.

Computer Generated Forces (CGF) are computer representations of entities in simulations, which attempts to model human behaviour sufficiently so that the forces will take some actions automatically. There are different layouts and architectures possible depending on the use of the system. The integration in the operational environment is a crucial point.

Human Behaviour Representation (HBR) offers support in different application areas; examples are thinking automated opposing forces (training and exercise), closed simulation systems (defence planning), Decision Support Tools (support to operations), and virtual environments (acquisition). Emerging technologies will have a great impact on the implementation and on the military use of such HBR in the future.

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ISBN 92-837-1085-1