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RESEARCH AND TECHNOLOGY ORGANISATION

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RTO MEETING PROCEEDINGS MP-094 **MSG-020**

NATO-PFP/Industry/National Modelling and Simulation Partnerships

(Les partenariats OTAN-PPP/Industrie/Nations en matière de modélisation et de simulation)

Papers presented at the NATO RTO Modelling and Simulation Conference held in Paris, France, 24-25 October 2002.

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The Research and Technology Organisation (RTO) of NATO

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

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

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

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS 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 co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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NATO-PFP/Industry/National Modelling and Simulation Partnerships

(RTO MP-094 / MSG-020)

Executive Summary

Introduction

The 3rd NATO Modelling and Simulation (M&S) Conference was held at the *Ecole Nationale Supérieure des Techniques Avancées* (ENSTA) in Paris, France, during the period 24-25 October 2002. It was organised by the NATO Modelling and Simulation Group (NMSG), administered by the NATO Modelling and Simulation Co-ordination Office (NMSCO), and was entitled "NATO-PFP/Industry/National Modelling and Simulation Partnerships".

Participation

The Conference was open to members of NATO nations and Partners for Peace nations (PfP), and was attended by 111 delegates. These were drawn from 26 nations, with France, the United Kingdom (UK) and the United States (US) having most representation, respectively. The non-NATO nations represented were: Armenia, Bulgaria, the Former Yugoslavian Republic of Macedonia (FYROM)*, Romania, Russia, Slovakia, Sweden, Ukraine and Uzbekistan. Of these, Bulgaria, the FYROM*, and Uzbekistan provided authorship of papers; the remaining authors originated from Canada, France, Germany, Italy, Poland, Spain, Turkey, the Netherlands, the UK and the US.

Most of the participants were NATO or national Defence employees, or representatives of commercial companies; 21 were from (military or civilian) academic institutions, 9 of which were authors of 4 associated papers; only 4 were drawn from civilian universities, 1 of which was the author of a paper, and 1 the author of this report. This would suggest that there is room for expanding the involvement of civilian academia in the activities of the Conference without distorting its Defence orientation.

Content, Structure and Organisation

The abstracts for 36 papers were submitted to the Conference Committee, of which 17 were selected for presentation. The selection approach used by the Conference Committee was firstly to evaluate the abstracts on quality, clarity and relevance to the Conference theme. A second sift was then undertaken to maintain a balance of papers from a broad cross-section of NATO and, in particular, PfP countries. 5 further papers were invited contributions which, together with the 3 keynote addresses, resulted in 25 presentations during the two days of the Conference.

Following the keynote addresses and (4 of the 5) invited papers, the Conference was divided into 5 sessions, with the last devoted to co-operation between NATO and PfP nations (which also contained a deferred invited presentation). The keynote addresses provided a useful context for the Conference, particularly with respect to the role of M&S within NATO and Defence, with Rear Admiral Gallagher's presentation setting an excellent standard at the outset. The invited papers and those in Session V then provided presentations which were closely allied to the theme of the Conference, reporting mainly on collaborative projects which had taken place, or providing useful information for those wishing to embark upon such collaborative ventures. In contrast, the papers of Sessions I – IV were less allied to the theme of the Conference, but provided useful material concerning activities associated with the usage (I & II) and development (III & IV) of M&S technology.

General Technical Assessment

The theme of the Conference was not specifically concerned with technical matters, so it would be wrong to judge its effectiveness on technical grounds alone. Moreover, technical assessment is very subjective, inevitably reflecting the technical background and sympathies of the evaluator. With these caveats, the bulk of the technical material of the Conference was contained in Sessions II – IV, and was generally of a good standard. Paper #11, presented by Ms Harrison, and Paper #16, given by Dr Menzler, were particularly impressive; the first, illustrating how far M&S has come in absorbing and extending the state-of-the-art in software engineering, to achieve reusability and interoperability; the second, providing a highly-relevant conceptual understanding of the issues involved in the

* Turkey recognizes the Republic of Macedonia with its constitutional name

interfacing of operational command systems with M&S. Other technical papers, of a more theoretical nature, were also of a good academic standard, but failed to engage the audience to the same extent, possibly reflecting the need for a bridge between this NATO M&S conference and academia, which would benefit both communities.

Key Outcomes and Conclusions

The Conference has clearly demonstrated the value of M&S as a vehicle for promoting and enabling collaboration and co-operation between national Governments, and between Governments and Industry. This derives from both the development and usage of networked simulations, particularly in the fields of Advanced Distributed Learning (ADL), Computer Assisted Exercises (CAX), Simulation Based Acquisition (SBA) and Synthetic Environment Based Acquisition (SeBA). However, there remain many areas where further work is needed if the potential benefits of M&S are to be fully realised, in this respect, and some key points are enumerated, below.

- Modern capability-led Defence acquisition approaches, which are being adopted by NATO Governments, will need 'system-of-systems' modelling, requiring:
  - non-technical issues such as doctrine, organisations and people, to be represented;
  - vertical and horizontal integration of models, and the need for M&S to operate at multiple levels of resolution within the mission space.
- The increasing need to support C4ISR[1] and NCW[2] operational concepts, will demand:
  - an improvement in the modelling of command & control and decision-making processes;
  - cost-effective techniques for interfacing operational command systems with simulations.
- Simulation Based Acquisition will require:
  - greater interoperability between disparate M&S software;
  - substantial changes of culture towards M&S sharing and reusability.
- Essential improvements in the interoperability and reusability of M&S will require:
  - greater emphasis on the Conceptual Modelling phase of simulation development;
  - architectural and development frameworks above that provided by the DoD's High Level Architecture (HLA) (which can remain as an effective foundation).
- Verification, Validation and Accreditation (VV&A) of M&S remains a major risk to the attainment of widespread reuse and interoperability, because:
  - there is no widely agreed VV&A framework between application domains;
  - there is a lack of standards, particularly at the Conceptual Modelling phase, and above.

In order to address these issues, it is vital that national Governments and Industry continue to invest in this field, particularly with regard to the development of standards, tools and infrastructures. Moreover, much more should be done to engage academia in this work, as recently proposed by a US National Research Council (NRC) study[3], and future NATO conferences in this series could play a pivotal role in encouraging this.

[1] Command, Control, Communications, Computers, Surveillance and Reconnaissance

[2] Network Centric Warfare

[3] See Paper #17 in Appendix A of this report.

Les partenariats OTAN-PPP/Industrie/Nations en matière de modélisation et de simulation

(RTO MP-094 / MSG-020)

Synthèse

Introduction

La troisième conférence de l'OTAN sur la modélisation et la simulation (M&S) s'est tenue les 24 et 25 octobre 2002 à l'*Ecole Nationale Supérieure des Techniques Avancées* (ENSTA) à Paris (France). Elle était organisée par le Groupe OTAN sur la modélisation et la simulation (NMSG), administré par le Bureau de coordination des activités de modélisation et de simulation de l'OTAN (NMSCO), sous le titre « Les partenariats OTAN-PPP/Industrie/ Nations en matière de modélisation et de simulation ».

Participation

La conférence, qui était ouverte à la participation de ressortissants des pays membres de l'OTAN et des pays du Partenariat pour la Paix, a accueilli 111 délégués. En tout, 26 pays étaient représentés, la France, le Royaume-Uni, et les États-Unis comptant respectivement le plus de représentants. Parmi les pays non-membres de l'OTAN représentés figuraient l'Arménie, la Bulgarie, l'ex-République yougoslave de Macédoine (FYROM)*, l'Ouzbékistan, la Roumanie, la Russie, la Slovaquie, la Suède et l'Ukraine. La Bulgarie, la FYROM* et l'Ouzbékistan ont présenté des communications, tout comme l'Allemagne, le Canada, l'Espagne, les États-Unis, la France, l'Italie, les Pays-Bas, la Pologne, le Royaume-Uni et la Turquie.

La plupart des participants étaient soit des fonctionnaires de l'OTAN ou des fonctionnaires de la défense nationale, soit des représentants de sociétés commerciales. Vingt-et-un d'entre eux appartenaient à des établissements d'enseignement supérieur (militaires ou civils), dont neuf étaient les auteurs de quatre communications associées ; quatre seulement représentaient des universités civiles, dont un était l'auteur d'une communication et un autre l'auteur du présent rapport. Ce bilan laisse supposer qu'il y aurait lieu d'impliquer un peu plus les universitaires dans les activités de la conférence sans pour autant modifier son orientation axée sur la défense.

Contenu, structure et organisation

Les résumés de 36 communications ont été soumis au comité de la conférence, dont 17 ont été retenus pour être présentés. La méthode de sélection adoptée par le comité de la conférence consistait à évaluer dans un premier temps les résumés eu égard à leur qualité, leur clarté, et leur pertinence par rapport au thème de la conférence. Il a été procédé ensuite à un deuxième tri, destiné à assurer une bonne représentativité des différents pays de l'OTAN et des pays du Partenariat pour la Paix. En incluant cinq autres communications présentées sur invitation, ainsi que les trois discours d'ouverture, en tout, vingt cinq exposés ont été présentés au cours des deux journées de la conférence.

Après les discours d'ouverture et quatre des cinq communications présentées sur invitation, la conférence a été divisée en 5 sessions, dont la dernière était consacrée à la coopération entre l'OTAN et les pays du PfP (y compris une communication présentée sur invitation reportée). Les discours d'ouverture ont permis de définir le contexte de la conférence, en particulier concernant le rôle de la M&S au sein de l'OTAN et de la défense, l'exposé du contre-amiral Gallagher établissant dès le début une communication d'excellent niveau. Les exposés sur invitation, ainsi que ceux de la session V, correspondaient parfaitement au thème de la conférence, puisqu'ils concernaient principalement des projets réalisés en collaboration, sources d'informations précieuses pour tous ceux souhaitant entreprendre de tels projets. À l'inverse, les communications des sessions I à IV étaient moins en relation avec le thème de la conférence, même si elles fournissaient des informations utiles concernant les activités associées à l'utilisation (I et II) et au développement (III et IV) des technologies de la M&S.

Evaluation technique générale

La conférence ne concernait pas spécifiquement des questions techniques. Par conséquent, il serait erroné d'évaluer son efficacité uniquement par rapport à des critères techniques. D'ailleurs, l'évaluation technique reste très subjective, reflétant inévitablement le cursus technique et les préférences de l'évaluateur. Avec ces réserves, nous constatons que la plupart des textes techniques ont été présentés lors des sessions II à IV et qu'en général ils étaient d'un bon niveau. La communication #11, présentée par Ms Harrison, et la communication #16, présentée par le Dr. Menzler, étaient particulièrement remarquables : la première démontrant les progrès réalisés par la M&S

* La Turquie reconnaît la République de macédoine sous son nom constitutionnel

dans la prise en compte et le développement des connaissances en génie logiciel en vue de la réutilisation et de l'interopérabilité ; la deuxième fournissant un aperçu conceptuel très pertinent des interfaces entre les systèmes de commandement opérationnels et la M&S. D'autres communications présentées, de caractère plus théorique, et qui étaient également d'un bon niveau académique, n'ont pourtant pas suscité le même intérêt auprès des participants, ce qui refléterait la nécessité de créer une passerelle entre cette conférence OTAN sur la M&S et les universitaires, au profit des deux communautés.

Résultats clés et conclusions

La conférence a clairement démontré l'intérêt de la M&S en tant qu'intermédiaire pour promouvoir et faciliter la collaboration et la coopération entre les gouvernements des pays membres ainsi qu'entre les gouvernements et l'industrie. Cet intérêt découle du développement des simulations en réseau et du recours à celles-ci, en particulier dans les domaines de l'apprentissage à distance avancé (ADL), des exercices assistés par ordinateur (CAX), de l'acquisition basée sur la simulation (SBA) et de l'acquisition basée sur les environnements synthétiques (SeBA). Cependant, il existe encore de nombreux domaines où des travaux supplémentaires sont nécessaires afin de pouvoir profiter de tous les avantages de la M&S. À ce propos, un certain nombre de points clés sont énumérés ci-dessous.

- Les approches modernes basées sur les capacités, adoptées par les gouvernements des pays membres de l'OTAN en matière d'acquisitions pour la défense, nécessiteront la modélisation de « systèmes de systèmes » impliquant :
  - la représentation d'éléments non techniques, tels que la doctrine, les organisations et le personnel ;
  - l'intégration verticale et horizontale des modèles, ainsi que la mise en oeuvre nécessaire de la M&S à de multiples niveaux de résolution au sein de l'espace opérationnel.
- La demande croissante de soutien pour les concepts opérationnels C4ISR[1] et NCW[2] nécessitera :
  - l'amélioration de la modélisation des processus de commandement et contrôle et de prise de décisions ;
  - des techniques rentables pour assurer l'interface entre les systèmes de commandement opérationnels et les simulations.
- L'acquisition basée sur la simulation nécessitera :
  - une plus grande interopérabilité entre les logiciels M&S disparates ;
  - une évolution considérable des mentalités en ce qui concerne le partage et les possibilités de réutilisation des moyens M&S.
- Des améliorations indispensables au niveau de l'interopérabilité et des possibilités de réutilisation de la M&S nécessiteront :
  - d'accorder plus d'importance à la phase de modélisation conceptuelle lors du développement de la stimulation ;
  - l'établissement de programmes de référence pour les architectures et pour le développement, en plus de ceux fournis dans le cadre de l'architecture de haut niveau (HLA) du DoD (lesquels peuvent être retenus car ils constituent des bases solides).
- La vérification, la validation et l'accréditation (VV&A) de la M&S représentent toujours un obstacle majeur à la généralisation de la réutilisation et de l'interopérabilité, puisque :
  - il n'existe pas de cadre VV&A communément accepté couvrant les différents domaines d'application ;
  - il manque des normes, en particulier en ce qui concerne la phase de modélisation conceptuelle et les phases supérieures.

Afin de permettre l'examen de ces questions, il est essentiel que les gouvernements des pays membres et les industriels continuent d'investir dans ce domaine, en particulier en ce qui concerne le développement de normes, d'outils et d'infrastructures. En outre, il conviendrait de faire beaucoup plus en vue d'impliquer les universitaires dans ces travaux, comme il a été proposé récemment dans une étude de l'US National Research Council (NRC)[3]. Ainsi, de futures conférences de l'OTAN sur ce même sujet pourraient jouer un rôle clé dans la promotion de cette démarche.

[1] Commandement, contrôle, communication, informatique, renseignement, surveillance et reconnaissance

[2] Conduite de la guerre orientée réseau

[3] Cf. exposé #17 à l'appendice A au présent rapport.

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† Paper not available for Publication due to Classification.

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Technical Evaluation Report

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INTRODUCTION

The 3rd NATO Modelling and Simulation (M&S) Conference was held at the *Ecole Nationale Supérieure des Techniques Avancées* (ENSTA) in Paris, France, during the period 24-25 October 2002. It was organised by the NATO Modelling and Simulation Group (NMSG), administered by the NATO Modelling and Simulation Co-ordination Office (NMSCO), and was entitled 'NATO-PfP/Industry/ National – Modelling and Simulation Partnerships'.

This document, which provides a technical evaluation and report on the Conference, is structured in two parts. First, the main body contains a brief discussion of some key features of the Conference, together with an overall technical assessment, and some key outcomes and conclusions; necessarily, this carries the subjective views of the author. Secondly, Appendix A provides an objective summary of each paper's presentation, together with an account of any ensuing questioning and attendant discussion, to provide a formal record of the proceedings. Note that, where the account of a presentation carries no questioning, then this means that either there was no time available for questioning, or that no questions were raised.

PARTICIPATION

The Conference was open to members of NATO nations and Partners for Peace nations (PfP), and was attended by 111 delegates. These were drawn from 26 nations, with France, the United Kingdom (UK) and the United States (US) having most representation, respectively. The non-NATO nations represented were: Armenia, Bulgaria, the Former Yugoslavian Republic of Macedonia (FYROM)[1], Romania, Russia, Slovakia, Sweden, Ukraine and Uzbekistan. Of these, Bulgaria, the FYROM[1], and Uzbekistan provided authorship of papers; the remaining authors originated from Canada, France, Germany, Italy, Poland, Spain, Turkey, the Netherlands, the UK and the US.

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CONTENT, STRUCTURE AND ORGANISATION

The abstracts for 36 papers were submitted to the Conference, of which 17 were selected for presentation. The selection approach used by the Conference Programme Committee was firstly to evaluate the

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abstracts on quality, clarity and relevance to the Conference theme. A second sift was then undertaken to maintain a balance of papers from a broad cross-section of NATO and, in particular, PfP countries. Five (5) further papers were invited contributions which, together with the 3 keynote addresses, resulted in 25 presentations during the two days of the Conference.

Following the keynote addresses and (4 of the 5) invited papers, the Conference was divided into 5 sessions, with the last devoted to co-operation between NATO and PfP nations (which also contained a deferred invited presentation). The keynote addresses provided a useful context for the Conference, particularly with respect to the role of M&S within NATO and Defence, with Rear Admiral Gallagher's presentation setting an excellent standard at the outset. The invited papers and those in Session V then provided presentations which were closely allied to the theme of the Conference, reporting mainly on collaborative projects which had taken place, or providing useful information for those wishing to embark upon such collaborative ventures. In contrast, the papers of Sessions I – IV were less allied to the theme of the Conference, but provided useful material concerning activities associated with the usage (I & II) and development (III & IV) of M&S technology.

The organisation of the Conference was very good throughout, with Session Chairs doing an excellent job in keeping the Conference running on schedule, in a polite and courteous fashion. The presentation of papers was generally very good, but the large number of presentations, and the tendency for some presenters to include too much material, limited the opportunity for substantial discussions. Reducing the number of presentations, and providing guidance on the maximum number of slides employed, would help to overcome this problem, as would the allocation of time to one or more Panel Sessions.

GENERAL TECHNICAL ASSESSMENT

The theme of the Conference was not specifically concerned with technical matters, so it would be wrong to judge its effectiveness on technical grounds alone. Moreover, technical assessment is very subjective, inevitably reflecting the technical background and sympathies of the evaluator. With these caveats, the bulk of the technical material of the Conference was contained in Sessions II – IV, and was generally of a good standard. Paper #11, presented by Ms Harrison, and Paper #16, given by Dr Menzler, were particularly impressive; the first, illustrating how far M&S has come in absorbing and extending the state-of-the-art in software engineering, to achieve reusability and interoperability; the second, providing a highly-relevant conceptual understanding of the issues involved in the interfacing of operational command systems with M&S. Other technical papers, of a more theoretical nature, were also of a good academic standard, but failed to engage the audience to the same extent, possibly reflecting the need for a bridge between this NATO M&S conference and academia, which would benefit both communities.

From a more personal perspective, it was, perhaps, surprising that the *technical* issues associated with the validation and verification of M&S did not achieve more coverage in the various papers; especially, given the widespread acceptance at the Conference that this issue has the potential to limit the reusability and interoperability of M&S, and that there is a lack of consensus on how to proceed.

KEY OUTCOMES AND CONCLUSIONS

The Conference has clearly demonstrated the value of M&S as a vehicle for promoting and enabling collaboration and co-operation between national Governments, and between Governments and Industry. This derives from both the development and usage of networked simulations, particularly in the fields of Advanced Distributed Learning (ADL), Computer Assisted Exercises (CAX), Simulation Based Acquisition (SBA) and Synthetic Environment Based Acquisition (SeBA). However, there remain many areas where further work is needed if the potential benefits of M&S are to be fully realised, in this respect, and some key points are enumerated, below.

- Modern capability-led Defence acquisition approaches, which are being adopted by NATO Governments, will need 'system-of-systems' modelling, requiring:
  - non-technical issues such as doctrine, organisations and people, to be represented;
  - vertical and horizontal integration of models, and the need for M&S to operate at multiple levels of resolution within the mission space.

- The increasing need to support C4ISR[1] and NCW[2] operational concepts, will demand:
  - an improvement in the modelling of command & control and decision-making processes;
  - cost-effective techniques for interfacing operational command systems with simulations.

- Simulation Based Acquisition will require:
  - greater interoperability between disparate M&S software;
  - substantial changes of culture towards M&S sharing and reusability.

- Essential improvements in the interoperability and reusability of M&S will require:
  - greater emphasis on the Conceptual Modelling phase of simulation development;
  - architectural and development frameworks above that provided by the DoD's High Level Architecture (HLA) (which can remain as an effective foundation).

- Verification, Validation and Accreditation (VV&A) of M&S remains a major risk to the attainment of widespread reuse and interoperability, because:
  - there is no widely agreed VV&A framework between application domains;
  - there is a lack of standards, particularly at the Conceptual Modelling phase, and above.

In order to address these issues, it is vital that national Governments and Industry continue to invest in this field, particularly with regard to the development of standards, tools and infrastructures. Moreover, much more should be done to engage academia in this work, as recently proposed by a US National Research Council (NRC) study[3], and future NATO conferences in this series could play a pivotal role in encouraging this.

[1] Command, Control, Communications, Computers, Surveillance and Reconnaissance

[2] Network Centric Warfare

[3] See Paper #17 in Appendix A of this report.

Appendix A – Summary of Proceedings

OPENING SESSION

Introduction from the Conference Committee Chairman

Mr G. BURROWS, Head, RTA/NMSCO, UK

Mr Graham Burrows, Head of the NATO Modelling and Simulation (M&S) Co-ordination Office, opened proceedings by welcoming participants as Chair of the Organising Committee of this 3rd Conference of the NATO M&S Group. He introduced the theme of the conference by emphasising the importance of setting up early partnerships between NATO, its partners, industry and national organisations, in order to achieve the successful implementation of M&S activities. He reflected upon the continuing high standard of papers submitted to the conference, of which approximately only half could be presented within the two-day duration, and thanked the Conference Programme Committee for their sterling work during the difficult task of making the final paper selections. He hoped that the collective content of these papers would provide participants with lessons learnt from existing partnering arrangements, and suggest ways forward for better partnering to support M&S objectives.

Host Nation Welcome Address and Administrative Announcements

ICA A. DUNAUD, DGA/DSP/SASF, Armées, FR

Colonel Alain Dunaud works with the procurement agency of the French Ministry of Defence (DGA). Amongst his numerous senior responsibilities within the DGA, Colonel Dunaud co-ordinates the M&S and decision-aid programmes for the French Armed Forces and, since November 1999, has also been part of the NATO M&S activities. He emphasised the importance of M&S to the French Ministry of Defence (MOD), particularly with regard to establishing operational requirements, validating system designs prior to construction, and optimising system use for operational effectiveness. He anticipated that these issues would re-surface throughout the conference, during the various presentations, because of their central importance.

NATO Keynote Address

NATO Transformation – Implications for NATO Modeling and Simulation

Rear Admiral R. K. GALLAGHER (US), SACLANT

Rear Admiral Gallagher, of the US Navy, is the Deputy Assistant Chief of Staff, responsible for Policy, at SACLANT HQ. A fighter pilot in origin, he has a user view of M&S, and has been impressed with the continual improvement in simulation capabilities from the rudimentary trainer of the F4 Phantom, through to the situation today, where pilots pre-fly their missions on-board an aircraft carrier with simulations which use real imagery. Consequently, M&S now provides an invaluable operational tool to improve combat effectiveness and reduce losses.

Rear Admiral Gallagher explained the rationale for NATO's transformation, in terms of changes to the international Defence environment, such as the rise in asymmetric threats and the continuing role for coalition peace-supporting activities involving Partner nations and other international organisations. The implications are that NATO will require new concepts, doctrine, plans, and training organisations, as well as more flexible joint, multinational structures. Importantly, the attendant transformation process must be proactive, identifying the future environment and required capabilities, developing new concepts, experimenting with these via M&S, and implementing changes to military capabilities of member nations (and others) through the planning process. Transformation is already underway with new concepts such as

High Readiness Forces and Distributed Training and Simulation being developed. Organisational changes include harmonisation of doctrine, equipment and training, and the structural re-organisation of NATO into Operational and Functional Commands.

The implications of NATO's transformation for the M&S community were presented by Rear Admiral Gallagher under the areas of: Analysis of Military Capability Need; Concept Development; Concept Experimentation; and Operational Training and Exercises. For the Analysis of Capability Need, M&S will be required to address the new situations that are likely to confront NATO, in order to assess various response options. This will involve not only traditional combat, but peace keeping, information operations, and managing the consequences of terrorist attack. Specifically, models should reflect the increasing tendency for joint and coalition operations, and the need for interoperability with various military and civilian organisations in both NATO and non-NATO countries. For Concept Development, it will be necessary to evaluate the impact of new technologies, and to analyse the effect of decision-making processes in combined and joint operations. It will be important to represent all military functions but, at present, some (e.g. logistics) are better served than others (e.g. information operations). Concept Experimentation will require wargaming models to be adaptable to the concepts being evaluated, and to enable a mix of live and simulated groups and assets. Finally, for future Operational Training and Exercises, it will be necessary to establish new M&S tools, such as Advanced Distributed Learning (ADL) packages to provide pre-exercise training anywhere and at anytime. Such tools will need to be multi-resolution, to support their use at different operational levels, and be integrated into Command, Control and Intelligence Systems (CCIS), to allow them to be used as decision aids during real operations.

In summary, Rear Admiral Gallagher emphasised the importance of M&S to the NATO transformation process, and posed four questions, for consideration by the Conference, relating to how this NATO M&S capability should develop. To what extent should individual NATO countries rely on the M&S facilities of member nations, as opposed to an in-house NATO capability? Is there a need for a common NATO M&S backbone? Should there be a NATO Simulation Centre? Can these questions be resolved by the Concept Development and Experimentation phases of the NATO transformation process?

Following the presentation, two questions were raised from the audience: the first related to the potential use of a NATO Simulation Centre; the second, regarding the security implications of distributed M&S within NATO. In response to the first question, Rear Admiral Gallagher suggested that a NATO Simulation Centre could be used, by NATO, in much the same way as the Joint Forces Command facility, in Virginia, is employed by the US Armed Forces. The latter facility is used to allow the integration of forces to be studied and predicted, and to enable requirements in individual areas to be harmonised within the overall concepts of the Joint Forces Command. In response to the second question, Rear Admiral Gallagher confirmed that having a classified capability was key to being able to share sensitive intelligence data, and play in scenarios at a classified level. Consequently, computer and network security was an important attribute of any NATO M&S facility.

French Military Keynote Address

Ingénieur Général de Division P. AUROY, Service d'Architecture des Systèmes de Forces, DGA/DSP/ SASF, Armées, FR

Paper not published due to classification. A copy may be obtained by contacting Col. A. Dunaud at alain.dunaud@cedocar.fr.

French Industry Keynote Address

Vues de l'industrie française dans le domaine de la modélisation et de la simulation /
Views of the French Industry in Modelling and Simulation
M.G. DELEVACQUE, Président Directeur Général Thalès Training & Simulation, Osny, FR

Mr Delevacque is the General Manager of Thales Training & Simulation. His presentation addressed four main issues: the evolution of M&S usage; associated technological developments and their consequences; partnering within research programmes; and some Industry views on future M&S funding.

The main uses of M&S were discussed under the headings of Training, Operational Analysis, and Through-life Support. Simulation-based training has evolved from equipment-oriented individual-operator trainers, to collective decision-making trainers that provide a realistic tactical environment. Mr Delevacque quoted two systems that Thales has recently delivered in this latter area: one for Army Captains, the other for Helicopter Pilots. With regard to Operational Analysis, this remained very much the domain of the Military, but Industry could provide its trainers and simulations to MODs, to allow them to determine what functionality they might require of their future systems. Through-life Support was considered as a very important growth area. Traditionally, M&S has mainly been used during the design phase of equipments, but the *cradle-to-grave* use of M&S, especially in the early concepts stage, and linking all subsequent stages, is considered as the way ahead. The UK has led this approach in Europe with its Synthetic Environment Based Acquisition (SeBA), and Thales has been developing its own capability in this area, and has been supporting UK MOD with its Future Carrier project.

Technology evolution has drastically reduced the costs of standard hardware and software, particularly in the Personal Computer (PC) applications area. M&S has exploited this, but bespoke M&S software remains very expensive to develop. However, developments in automatic code generation from high-level designs (e.g. in UML) and model reuse (e.g. in HLA) offers potential cost reductions. Interoperability between M&S is critical to effective reuse, and the adoption of M&S architectural frameworks is important here. Unfortunately, the proliferation of frameworks is likely to escalate M&S development costs, and the adoption of a single homogenous framework should be pursued.

With regard to collaborative programmes within Europe, Mr Delevacque considered that there had been good co-operation in the development of products, such as Eurofighter, but that co-operation in research had not been satisfactory. This, he considered, to be due to the poor research and development (R&D) budgets, the bureaucracy of R&D programmes, and the slow rate of funding which caused delays that were incompatible with the fast technology evolution in this computing area.

In response to the final issue of his talk, Mr Delevacque suggested what Thales would like to see happen for M&S funding within Europe. First, more investment was needed for Defence R&D in Europe; Industry cannot fund this area alone; leveraging off the civilian commercial sector will not be sufficient on its own. Secondly, there is a need for a new (4-year) R&D programme across NATO and its Partners, using a central funding arrangement, which would allow Industry consortia to be formed by optimising their expertise, and not simply on the basis of equal geographical distribution of the funds.

Following the presentation, two questions were raised from Canadian participants, relating to problems that the Canadian Army had when trying to connect a constructive simulation to a Thales Command Support system that was equipped with embedded training. Given the emphasis Mr Delavacque had placed upon the need for interoperability between M&S software, these participants wondered why their integration task had been so problematical, eventually requiring a bespoke interface to be constructed. Mr Delevacque was not familiar with the precise details of this problem, but indicated that the Command Support system had been procured a few years ago, when there was not a good understanding of potential interoperability requirements. Consequently, the required interfacing features were not provided.

In addition, he commented upon the on-going need, in large international companies like Thales, for horizontal integration between departments, in order to facilitate interoperability between separate company products.

INVITED PRESENTATIONS

Session Chair: Mr E. SCHWAN, GE

Paper #1

Regional Security Cooperation Through Education and Training Technology
Mr J. BOLCAR, JWFC, Suffolk, VA, USA and Mr W. CHRISTMAN, REN, Europe, Geneva, Switzerland

The paper was presented by Mr W. Christman who is the European Programme Manager for the US Joint Forces Command (JFC) Regional Engagement Network (REN). Mr Christman explained that the US DoD had entrusted, to the JFC, the task of helping each of the regions of the world to become self-reliant for their security, via the establishment of common procedures and tactics that would be consistent with those of the US. This would allow the US to stand back from regional security affairs, but be in a position to help out if required. Accordingly, the JFC is developing a Regional Security Cooperation Network (RSCN) whose objectives are: to help allies, friends and potential coalition partners to conduct coalition operations and defend themselves; to develop long-term military ties; and to sustain NATO as the pre-eminent European security institution by improving members' capabilities.

The RSCN objectives are being pursued using a *Triad of Technology* comprising: Distributed Simulation, Advanced Distributed Learning (ADL), and Digital Reference Libraries. The approach is to exploit existing technology and facilities, to provide cost-effective education and training across global coalitions. The underlying military concept is that, by using the RSCN approach to enable peace-time operations, the resultant co-operation and interoperability (of minds) will promote global stability and security.

In keeping with the thrust of the presentation, ADL was singled out for special attention, and requires: Technology, especially that associated with the Internet and multimedia; Content, including curricula and courseware; and a Learning Management System, supporting activities such as testing and reporting. Its (ambitious) goal is to provide the means to learn *anytime and anywhere*. Through the development of ADL, and its integration with Command Post Exercises (CPX) and Computer Assisted Exercises (CAX), various NATO/PfP objectives, priorities and M&S tasks will be supported. Consequently, plans are in place to develop a NATO ADL capability, involving the NATO Defence College and the NATO School (SHAPE), and to integrate this with a CPX/CAX event. Already, various co-operative ADL activities have started involving Canada, Bulgaria, Russia, Sweden, Switzerland and the Ukraine.

Even without ADL, distributed simulation-based exercises (CAX) remain an important approach for achieving RSCN objectives, and three recent examples of these were presented, one of which was the Viking Exercises. These are based upon peace support operations, the last of which (Viking 01) involved 5 sites, 17 nations and 450 participants. More significant, however, is Viking 03, which will act as a test bed for integrating ADL with distributed CAX, to develop a template for conducting training in a new way. This will support the long-term vision of using ADL, Distributed CAX and Digital Libraries, for multinational exercises associated with Peace Support Operations, Humanitarian Assistance and Disaster Relief; thus, providing a practical, operational approach for enhancing PfP, as directed by the Washington summit.

Paper #2

NATO Lessons Learned from Dealing with MOU and Contractual Issues with Government and Industry – the NC3A Experience
Mrs S. ROCCHI, NC3A, Brussels, BE

Paper not published due to classification. A copy may be obtained by contacting Mrs S. ROCCHI at simona.rocchi@nc3a.nato.int.

Paper #3

Working with Industry – The UK MoD Experience
Mr A.J. FAWKES, MOD/UK/SECO – DG(R&T), London, UK

Mr Fawkes is Head of the Synthetic Environments Co-ordination Office (SECO) of the UK MOD, and has recently been appointed as the Vice Chair of the NATO M&S Group. The thrust of his paper was that the UK MOD's progress in the area of synthetic environments (SEs) could not have been achieved without the support of UK industry, and that SEs have proved a good vehicle for fostering collaboration between UK MOD and Industry, aiding mutual understanding between Government organisations and companies. His presentation was divided into four parts: an overview of UK MOD's approach to SEs; the potential benefits of working with Industry on SEs; a brief history of the UK SE programme with Industry; and UK MOD's current arrangements for fostering continued collaboration with Industry in the field of SEs.

In his overview of UK MOD's approach to SEs, Mr Fawkes introduced the operational Defence context within which the SE programme had been developed, in terms of uncertain threats and increasing joint & multi-national operations. In this setting, SEs are considered to have a significant role to play in improving Military capability, particularly with respect to Smart Equipment Acquisition, Networked Enabled Capability (UK MOD's approach to Network Centric Warfare), and Training (especially deployable & collective). Typically, UK MOD and Industry spend £100m's per annum on M&S, and the idea of the SE programme is to exploit this by extending the use of M&S across Defence processes and stakeholders; essentially, linking people, M&S models and equipments together, to address through-life issues associated with the people, processes and equipments which define Military capabilities. However, there remain substantial challenges to overcome, which are socio-technical in nature, ranging from understanding the rapidly changing technologies, through contractual issues involving Intellectual Property Rights (IPR), to human aspects associated with retention of expertise. Nevertheless there had generally been good progress, and eleven examples of current SEs were identified by Mr Fawkes in the Acquisition and Training areas, some of which would be described later in his presentation.

Mr Fawkes introduced the manifest need for UK MOD to work closely with Industry by observing that MOD no longer develops materiel, and it is only through Industry that it can procure front-line or training equipment. From the outset, both Industry and MOD recognised the potential for SEs to strengthen partnerships. Importantly, what has emerged from the UK's SE programme is that they also offer the potential for greater cost-effectiveness and consistency, through sharing of data & knowledge, working to agreed standards, and gaining a better mutual understanding of Defence processes.

The history of the UK's SE programme was described by Mr Fawkes, starting with the SE Research Initiative (SERIN) in 1993, which first brought together MOD and Industry to discuss a way forward. A landmark in this process occurred in 1995 with the formation of a joint (MOD/Industry/Academia) SE Management Board (SEMB) which, in turn, led to the formation of a National Capability Demonstrator (NCD) programme, to pioneer the introduction of SE-based approaches to Defence products and processes. The presentation discussed the role of the NCD programme, and described six major NCD projects, starting with FLASHLAMP, which investigated the use of the US DoD's High Level

Architecture (HLA) during the period 1996-98, and including more recent examples, such as the Future Offensive Air System (FOAS) SE, which was demonstrated in July 2000, across 3 geographically-distributed sites, and involved real-time man-in-the-loop simulation with 24 discrete federate systems and over 400 air and surface entities. In addition to UK-centred research, Mr Fawkes also commented upon UK MOD's SE-based involvement with other nations, particularly under area "11.13" of the European Cooperation for the Long-term in Defence (EUCLID 11.13) programme, which is funded by various MODs and Industry (17m euros) over the period November 2002 to October 2003 (see Paper #22).

Finally, in his presentation, Mr Fawkes explained the three current organisational bodies which exist to further co-operation between UK MOD and Industry in the SE field. First, the aforementioned SEMB, which maintains a web site at www.semb.co.uk, and is currently considering how the UK MOD's NEC initiative may be supported by SEs. Secondly, the SE National Advisory Council (NAC) to the UK Government, which is provided by the SEMB, and has identified a number of areas for improvement to SEs, and agreed the launching of a SE initiative under the UK MOD's 'Towers of Excellence' programme. Thirdly, there is the Synthetic Environment Based Acquisition (SeBA) Forum, which is intended to continue the evolution of the ideas generated from the SeBA NCD project which ran from 1998-2002.

Following the presentation, a German delegate asked if the presenter foresaw the need for a SE approach beyond that provided by HLA, which would be common across NATO, that would allow the Verification, Validation and Accreditation (VV&A) of M&S to be managed. Mr Fawkes replied that there was a need for the UK MOD to better understand how it would ensure that what Industry was producing, in terms of M&S and SEs, was cost-effective and valid, but that no clear ideas of how to proceed currently existed. UK MOD needed to move beyond its current demonstrator programme because there was no coherent approach to the VV&A issue, and this was the type of problem that needed to be addressed by this conference.

Paper #4

Partnerships that Work! A Review of US Government – Industry Cooperative Research Agreements
Dr G.W. ALLEN, AMC Liaison Officer to BWB, Koblenz, GE

Dr Allen spent 29 years with the US Army, where he specialised in M&S, and retired in the rank of Lieutenant Colonel. Since retiring from Military service, he has spent several years working in Industry, and is now the US Army Liaison officer to the German Federal Office of Defence for Technology and Procurement (BWB). Dr Allen's presentation addressed the following topics: the US legal background to Government-Industry co-operative research agreements; the types of US agreements; the approval process for such agreements; and an example of a successful collaborative agreement.

The legal background was presented, historically, in terms of three US laws, which have progressively attempted to make Government-Industry co-operation easier and more profitable. The last of these was the National Technology Transfer & Advancement Act of 1995, which protected the Intellectual Property Rights (IPR) of Industry, to encourage early exploitation of collaboration outputs via product development, and provided incentives for Government staff to engage in such collaboration. Importantly, authority for such agreements was devolved down to the Head-of-Laboratory level, on the Government side.

The two types of US Government-Industry agreement were defined as: the Material Transfer Agreement (MTA) and the Co-operative Research and Development Agreement (CRADA). A MTA would typically be employed by the Government when it wanted to stimulate Industry's own Research and Development (R&D) in a particular field; the Government would supply some of its own science or technology which would inform Industry's own R&D programme, but which must not be exploited directly for product development. An example from the medical field might be the Government supplying Industry with a virus, for which it wanted Industry to produce commercial vaccines. The CRADA is a more equal collaboration, where both Government and Industry share each other's resources to address a problem of common interest. No money changes hands, and IPR on both sides is guaranteed.

A simple five-stage process was described, which traced the steps from identifying a requirement for a Government-Industry agreement, through to implementing and delivering that agreement. Importantly, in the middle of this process was a legal review of the established terms of the proposed co-operation, which was needed to support the subsequent approval stage. This reinforces the point made earlier by Mrs Rocchi in Paper #2, that a legal team needs to be involved early in the process of establishing agreements.

The CRADA was presented as a particularly successful approach; Global Positioning System (GPS) handsets, graphite shafts for golf clubs, and instant coffee, were introduced as examples of commercial products which have resulted from this type of Government-Industry agreement. Within the M&S field, Dr Allen cited a specific example of the Reconfigurable Asymmetric ISR[4] Development (RAID), which he had been personally involved with, from the Industry side. This addressed a practical need of the Battle Command Battle Laboratory (BCBL), at the US Army Intelligence Centre, Fort Huachuca, Arizona, which was concerned with evaluating advanced concepts in the ISR domain. Initially, BCBL had intended evaluating concepts using pencil-and-paper exercises. However, after discussing the matter with a US company, Veridian, which had considerable M&S experience, a CRADA was set up between the US Army and Veridian, which resulted in the rapid delivery of an ISR toolset to the BCBL, based upon existing DoD M&S software, principally from the WARSIM and JSIMS projects. The US Army contributed resources to the project in terms of Subject Matter Experts (SMEs), a test bed, hardware and software, and work space at the BCBL; Veridian supplied programme management, software development, system integration, training and documentation. The benefits to the Government were seen as satisfying an un-funded requirement, achieving a quick response, and influencing the commercial market with regards to the products required for this type of Defence activity. For Industry, the benefits were considered to arise from the project's role in validating the market need for such products, the use of a real-world test bed, and the product-design input from the SMEs.

There was one question, following the presentation, from the Session Chairman who wondered what Industry perceived the 'win' to be from its investment. In responding, Dr Allen, who was responsible for initiating this CRADA while working at Veridian, indicated that Veridian had estimated that it would achieve a 30:1 return on investment, through anticipated further customers for this type of product.

SESSION I – NATO CO-OPERATIVE PROJECTS FOR TRAINING AND EXERCISING

Session Chair: Dr. Hans JENSE, NE

Paper #5

The Cost Effective Development of HLA Federations for Computer-Assisted Exercises (CAX)
Dr K. PIXIUS, BWB, Koblenz, GE

This presentation addressed two primary issues associated with improving the cost-effectiveness of NATO CAX facilities. First, there was a need to transition from the current NATO CAX arrangements, based upon interconnected monolithic simulations, which had to be tailored for each application, to a more

[4] Intelligence, Surveillance and Reconnaissance

flexible arrangement based upon the DoD's High Level Architecture (HLA), which would support the reuse of simulation federates. Secondly, there was a need to connect CAX systems directly to operational Command and Information Systems (CIS), to ensure the realism of the training experience, and to reduce the number of operators that were required to support a CAX facility.

The presentation addressed the above two issues by: considering the lessons learnt from experiments such as DiMuNDS 2000, and discussing their relevance to NATO's PATHFINDER project; briefly identifying the operational requirements for future CAX; discussing ways to address the coupling of CIS to M&S, to ensure interoperability; explaining how cost-effectiveness could be related to the technical and operational relevance of CAX systems; and discussing how commercial standardisation approaches, in particular the role of meta-modelling and Model Driven Architectures (MDA), could be gainfully employed to implement the required NATO CAX capabilities. Finally, the presentation provided short-, medium- and long-term recommendations to address the issues raised in this talk.

There was one question raised from the floor, which queried the basis upon which a graph, illustrating the predicted reduction in cost resulting from CAX-system improvements, was formulated. Dr Pixius indicated that this reduction in cost was based upon a quantifiable reduction in human operators needed to support a CAX arrangement. There would be other reductions in cost resulting from increased M&S reuse and flexibility, but these could not be quantified.

Paper #6

Mission Training Through Distributed Simulation – Contributing to Warfighter Integration
Mr J. van GEEST* and Mr B. TOMLINSON**, *TNO, The Hague, NE, ** QinetiQ, Bedford, UK

The presentation was given by Mr van Geest. It described the NATO initiative concerned with the use of networked aircraft simulators to provide mission training; that is, Mission Training through Distributed Simulation (MTDS). The background to MTDS was explained, in terms of a previous NATO study that had identified its potential advantages for sustaining and improving operational effectiveness for multi-national air operations. For example, it is agile to changing mission needs, and usable where flying restrictions and safety issues apply. Also, it is complementary to live training, which can focus on specific issues. In order to progress the concept though to realisation, NATO has recently formed a MTDS task group by combining existing task groups associated with distributed mission rehearsal for air operations (MSG-001) and MTDS concept development (SAS-034). The current emphasis of this combined task group is Exercise First WAVE (Warfighter Alliance in a Virtual Environment), which is a globally distributed training demonstrator due for completion in the first half of 2004.

The majority of the presentation was concerned with describing Exercise First WAVE, in terms of: its mission type of Composite Air Operations; the operational scenario to be used; the simulation assets to be employed, such as fighters, Command and Control (C2) systems, and sensors; other assets required, such as Computer Generated Forces (CGF), briefing and debriefing assets, and computer networks; the six participating nations and their roles; the various industrial partners; the focus areas which the combined task group must address to ensure the success of the venture; and the challenges which must be overcome. Importantly, Exercise First WAVE is not a technology demonstrator, as has been the case for a number of previous distributed simulation experiments, but will be evaluated in terms of its training capability. However, the system complexity is high, with an anticipated 19 sites distributed across Europe and North America, involving both wide-area and local-area networking, and security issues have yet to be fully defined and resolved. Moreover, the success of the venture will depend critically upon effective collaboration between the 6 member nations and their industrial partners, no doubt requiring substantial financial, administrative and contractual problems to be resolved.

Following the presentation, there was a question from a delegate, which was concerned with the security implications of Exercise First WAVE; for example, how to deal with the problem of individual nations' classified data being used in the demonstrator. He wondered if a multi-level security arrangement was envisaged. Mr van Geest replied that a multi-level security system would not be used. Instead, officials of the six national air forces concerned were meeting to identify data that could be seen by all participating countries, but which was still suitably classified so as not to detract from the realism of the training experience. Mr Tomlinson (co-author of this paper) added that the security problem is fundamental to this type of collaborative arrangement, and that they did not have all the answers yet, but that neither did anybody else. The Session Chairman concluded that, in keeping with Mrs Rocchi's presentation earlier, the fundamental need was to establish trust between collaborators, but that this is a slow process that will take time to achieve.

Paper #7

NC3A Simulation Support for Theater Missile Defence Operations in NATO Exercise Cannon Cloud 2002 (CC02)
Mr D. TAYLOR*, Dr D. COPPIETERS* and Mr P. VIERVEIJZER**, *NC3A, **TNO Physics and Electronics Laboratory, The Hague, NE

This presentation was given by Mr Taylor who was representing the NATO Consultation, Command and Control Agency (NC3A). He began his talk by briefly identifying the role of the NC3A within the NATO C3 Organisation, and describing the internal structure of the NC3A Directorate. The bulk of the talk was then spent introducing the NATO Exercise Cannon Cloud 2002 (CC02), describing the role of Theatre Missile Defence (TMD) within this, and detailing the way that existing M&S had been networked to achieve the required TMD simulation facility.

TMD was, in fact, a small part of Exercise CC02, which was a large, multi-corps CAX conducted at the USAF Europe Warrior Preparation Centre in Einsiedlerhof, Germany. Exercise CCO2, which was based upon the landscape of Northern Europe with fictitious national boundaries, employed the aggregate-level Joint Theatre Level Simulation (JTLS) to provide higher echelon operational training for coalition forces in a large-scale high-intensity conflict. A major development issue for the NC3A was to determine how to integrate the existing entity-level simulations, which would provide the TMD operations of Exercise CC02, with the aggregate-level JTLS that formed the primary simulation of this CAX. There were three aspects to the TMD operations: Active Defence (AD), which was concerned with engaging a missile in flight; Passive Defence (PD), such as the use of camouflage, deception, early warning, etc; and Conventional Counter Force (CCF), which was concerned with preventing an aggressor from launching missiles by attacking associated launch sites. In the case of AD and PD, it was possible to drive this directly from JTLS, using appropriately developed interfaces. However, CCF required a separate entity-level representation of the battlespace upon which the required sensors could operate, and the integration problem became one of ensuring that the JTLS and CCF-required real-world representations were synchronised. This was achieved by driving both representations from the same script, and not allowing actions within the CAX to change the scenario dynamically.

The overall conclusions of the paper were that the NC3A approach for integrating entity-level simulations with JLTS, together with the TNO-developed HLA interface between JLTS and the AD simulations, had worked very well for supporting TMD in Exercise CC02. In addition, there were a number of more detailed conclusions relating to the particular simulations employed for the AD, PD and CCF capabilities, and regarding the way ahead for future work in this area.

In the subsequent question session, Dr Igarza asked Mr Taylor whether there were any likely alternatives to the use of JTLS in future Exercises. His question was prompted by his observation that JTLS was developed as a stand-alone aggregate-level simulation whose use would limit the dynamic properties of distributed interactive simulations. Mr Taylor responded by saying that, to address a future requirement of time-critical targeting, a Computer Generated Forces (CGF) approach was needed to provide the dynamic behaviour that was missing with the scripted JTLS approach. In fact, OneSAF and JointSAF would appear to be feasible alternatives to JTLS at the current time.

A further question from a delegate asked how the problem of aggregation and disaggregation was handled, given that aggregate-level representations from JTLS were used in conjunction with entity-level simulations. Mr Taylor replied that both representations were held, and implicitly synchronised through the common-scripting approach, but that this imposed limitations, as discussed previously. From the subsequent interchange between questioner and speaker, it was concluded that, even if all simulations were to work at the entity level, there would always be a need to hold some representations at the aggregate level. Therefore, the aggregation/disaggregation problem was a fundamental problem, and a multiple-resolution approach was needed to provide a more generally-applicable solution.

SESSION II – M&S IN SUPPORT OF MILITARY ACTIVITIES

Session Chair: ICA Alain DUNAUD, FR

Paper #8

A Multiagent Based Model for Tactical Planning
Major J.M. CASTILLO* and Professor F. DE ARRIAGA**, *Escuela de Informática del Ejército, **Universidad Politécnica de Madrid, Madrid, SP

This presentation was given jointly by Professor de Arriaga and Major Castillo. It provided the theoretical (artificial intelligence) underpinnings of a conceptual model for tactical planning, and described the results of employing this model for the construction of two prototype planning tools; one for artillery planning, the other for project management.

The tactical planning conceptual model takes, as inputs, the sets of resources available and tasks to be carried out and, importantly, the goals which a suitable plan must satisfy. The output is an optimised plan. Within the model there are four agents: a Classifier agent, which is concerned with identifying which resources are required by which tasks, and is based upon a neural network approach; a Quantifier agent, based upon fuzzy logic, which produces a number (or linguistic tag) to determine, for example, how well a particular resource fulfils a particular task; an Assigner agent, which employs intelligent searches to determine a set of possible plans; and an Optimiser agent which employs heuristics or genetic programming to speed up the processing of the Assigner agent.

The prototype artillery planning tool was successfully implemented using the above conceptual model, but did not require instantiation of the Quantifier agent. The project planning prototype tool required all agents of the model to be employed, and the presentation provided an example of its use, demonstrating the flexibility of the tool to produce a range of potential solutions, based upon different planning goals. Future work is intended to address a conceptual model for strategic planning, based upon a similar multi-agent approach, which would be capable of generating suitable mission scenarios and making a sensitive analysis of events.

The presentation prompted three questions from the floor. The first question asked for an explanation of the 'defuzzy' stage of the Quantifier agent, mentioned in the early part of the talk. Professor de Arriaga explained that fuzzy logic rules would normally produce a range of values (fuzzy set) as an output, but that the subsequent planning stages would require a single value. The conversion of the former to the latter was the role of the defuzzy stage.

The second question, from a NC3A representative, asked whether it was intended to interface the artillery planning tool to a C3I operational system or simulation. Professor de Arriaga explained that they were currently investigating this for the Spanish Government. Within two years, it is hoped that this planning tool will be integrated with suitable Spanish military systems. One potential application is to support the training of artillery officers, by allowing them to check how good their manually-derived plans are with respect to those optimal plans produced by the tool.

The third question asked whether it would be possible to replace the fuzzy logic, employed within the Quantifier, with random variables (with probability distributions) for time and cost, and to run the simulation many times and take averages. Professor de Arriaga indicated that this approach would probably result in the same solution, but that the fuzzy-logic approach offered two advantages. First, humans are used to dealing with fuzzy sets, thus the approach is more intuitively understandable. Secondly, if you are dealing with probabilities you must take Bayes theorem into account; that is, if an event occurs which changes your *a-priori* view, then all the probability distributions must be changed.

Paper #9

ITCS: l'infrastructure technique commune dédiée à la simulation pour l'acquisition /
ITCS: The Technical M&S Infrastructure for Supporting SBA Process
IETA L. KAM*, IPA X. LECINQ*, IETA P. CANTOT** and ICA D. LUZEAUX**, *DGA/DCE/CTA, 94114 Arcueil Cedex, **DSP/STTC/SC, 00303 Armées, FR

This paper was presented by Dr Kam, and described a project (ITCS) which is concerned with establishing a common technical infrastructure to support M&S within the DGA. The presentation identified: the (DGA) stakeholders for the ITCS; its objectives, application domain and architecture; related projects at both National, NATO and European levels; the ITCS project's work breakdown and schedule; and a report of progress, to date.

Importantly, the ITCS will support M&S for both the Analysis & Design of Defence Capabilities, as well as Acquisition & Procurement, from the Strategic (Joint) level down to the individual System level. It will include repositories for models, natural environment data and scenarios, to facilitate reuse, and also provide visualisation and post-processing facilities, simulation engines, global simulation integrators, and support for man-in-the-loop and hardware-in-the-loop simulation. The simulation networking will employ HLA, and data formats will be based upon SEDRIS.

Most of the related French national projects, upon which ITCS will draw, are associated with technology, especially that related to HLA. However, one process-oriented project (REVVA) is about to commence, which is concerned with a methodological framework for Verification, Validation & Accreditation (VV&A). Relevant NATO and EUCLID projects are associated with a simulation resource library, and an enhanced Synthetic Environment (SE) development process and toolset, respectively (see Paper #22).

Currently, the ITCS is just completing its functional requirements phase, and two contractors will start competitive studies in 2003, with the winning contractor scheduled to deploy version 1 of the ITCS on all DGA sites before the end of 2005. Thereafter, subsequent versions will be rolled out annually. As part of the functional requirements phase, there has been an extensive survey of existing M&S employed within the DGA, and an attempt to classify these simulations on the basis of system granularity. Overall, 50 functions have been identified for the ITCS, together with a characterisation of the M&S actor and user profiles, as well as a preliminary definition of repository and development services.

In conclusion, the DGA recognise the ambitious nature of the ITCS project, but has been encouraged by the positive effect it has had, to date, on moving participants towards a more collaborative and sharing culture. At the international level, the hope is that the ITCS project will incite Industrial companies and European/NATO partners to join in. At the domestic level, the hope is that ITCS will contribute to the success of Simulation Based Acquisition (SBA).

Three delegates raised questions regarding this presentation. First, a member of the French Armed Forces asked a three-part question: could ITCS be used for more general military applications; how could this approach be synchronised with NATO and Europe; and how might the ITCS be used to support Force System Architecture analysis work? Dr Kam replied that: the ITCS was not intended for general military application, but was centred on defence analysis and procurement; through participation in NATO and European programmes (e.g. EUCLID), the DGA could take account of European and NATO developments, and better understand military requirements; and the military could perhaps employ M&S at the Force System Architecture analysis level to provide cost models, but that the general use of M&S at this high level is difficult to envisage.

A second delegate asked whether there was a specific project that the ITCS was being developed for. Dr Kam indicated that he was not aware of any such project that was driving the development of the ITCS, but that he was more concerned with the architectural aspects of the work, and that somebody else from the DGA might be better placed to provide a definitive answer to this. He did, however, believe that the first project that would use the ITCS was likely to be the Future Air-Land Combat System “Bubble” project, referred to by General Auroy in his keynote address (and in Paper #15).

Finally, a third delegate asked a two-part question: what is the role of the global simulation integrator illustrated in the ITCS architecture; and are you thinking about developing your own process models, or are you going to use existing models such as the HLA FEDEP[5]? Dr Kam replied, respectively, that: the global simulation integrator holds a set of tools which define the sequencing of models to link with the input data; and we do not intend to re-invent the wheel, and are taking both the FEDEP and the SEDEP into account, but will also be looking to improve upon these, where appropriate.

Paper #10

Etude NIAG sur les modélisations et simulations en soutien des opérations de support de la paix /
NIAG Study on Modelling and Simulation Support to Peace Support Operations (PSO)
M.J.P. FAYE, Thales Raytheon Systems, Massy, FR

Mr Faye is the Chairman of a Study Group (SG67), of the NATO Industrial Advisory Group (NIAG), which is concerned with M&S for Peace Support Operations (PSO). SG67 is in the process of completing the report of its study, which will shortly be available via the NMSG Web site. The main purpose of Mr Faye’s presentation was to provide an overview of the results and conclusions of the study. However, he first provided a brief introduction to the organisational context in which SG67 operated, particularly with respect to the NMSG and its Group (MSG-004/24) concerned with Non-Article V activities (i.e. OOTW[6]). He also defined the six aspects of PSO, and distinguished PSO from Other Security Interests (OSI), which covers the remaining Non-Article V activities of NATO, such as Counter-Terrorism.

In presenting the results of the Study, Mr Faye started by defining the PSO M&S needs under the categories of Education, Training, Exercises, and Logistics & Planning, which were derived from existing NATO and US documents. He then defined the PSO modelling requirements, under the headings of Maritime, Land, Air, Joint Logistics, and other Joint Capabilities, such as Special Forces and Medical Services. A primary technical task of the study was to analyse 24 simulation and operational tools, to determine how well the PSO capability requirements were met. The results showed that: no one tool covered all PSO needs; there was a lack of a common data model across tools; and there was a lack of support for interfacing PSO M&S to CCIS because CCIS were only just beginning to address PSO-specific issues. Accordingly, recommendations are that: a M&S Common Data Model should be

[5] Federation Development and Execution Process

[6] Operations Other Than War

produced, based upon the NATO LC2IEM operational (CCIS) model and including extensions for PSYOPS and Joint operations; and legacy simulation systems should be extended to add PSO-specific M&S when required by a PATHFINDER federation. The technical work of the study also addressed the problems of interfacing M&S to CCIS. It was concluded that the interfacing of persistent data (e.g. geographic) was being addressed, to some extent, by the use of standards such as XML and SEDRIS; similarly, the interfacing of non-persistent data (e.g. orders and events), could be covered by HLA. However, the interfacing of control information had yet to be addressed.

Although not strictly part of PSO, the study also addressed M&S for Counter-Terrorism (CT), suggesting that a Geographic Information System (GIS) database, that was shared with PSO M&S, could be used for M&S tools associated with both proactive and reactive CT activities.

In conclusion, Mr Faye presented an action plan covering the main recommendations of the study. This consisted of four parallel streams covering the period 2003 – 2008, as follows: production of a Reference Scenario Data Model and Reference FOM[7]; the specification of PSO applications leading to a PSO Demonstrator; the development of appropriate M&S infrastructure; and the provision of CT Operations support tools. The proposal is that each of these streams would be supported by existing NMSG groups and projects.

Following the presentation, an issue was raised from the floor, relating to the production of FOMs. From experience with PATHFINDER, to date, it would appear necessary to have different FOMs for different applications areas. It would be nice to have a 'mother' FOM from which these could be derived but, in practice, this is likely to be very difficult to achieve. How did this compare to the conclusions of the study? Mr Faye replied that they felt that the notion of a Reference FOM would be useful to aid interoperability between simulations, but that this was not the same as a Reference Data Model, as proposed. The latter would hold information that would be used to create individual FOMs, which would be tailored to the needs of an application.

SESSION III – M&S DEVELOPMENT: TECHNOLOGY ADVANCES FOSTERING REUSABILITY AND INTEROPERABILITY

Session Chair: Dr Jean-Louis IGARZA, NMSCO, FR

Paper #11

A M&S Process to Achieve Reusability and Interoperability
Ms N. HARRISON, Mr B. GILBERT, Mr M. LAUZON, Mr A. JEFFREY, Ms C. LALANCETTE, Dr R. LESTAGE and Mr A. MORIN, Defence R&D Canada-Valcartier, Val Bélair, Québec, CA

This paper, presented by Ms Harrison, reported upon a process framework and associated toolset which had been devised to improve the reusability and interoperability of M&S software. The framework draws heavily on modern software engineering techniques and standards, and the toolset is largely based upon commercial products. The approach has been applied to a weapon engagement simulation, and the paper reported on this, together with attendant conclusions and proposed future work.

Importantly, the process framework starts with Conceptual Modelling, which is based upon the Unified Modeling Language (UML). This is followed by Scenario Modelling and Physical Modelling as parallel activities, leading to the automatic generation of the data and modelling components that form the required simulation. Scenarios are captured using the Extensible Markup Language (XML), and physical models are produced using either a conventional programming language such as C++, or a visual programming

7 HLA Federation Object Model

environment such as MATLAB. Model components are created as Dynamic Link Libraries (DLLs) which, together with the XML scenario file, are integrated into a commercial HLA-based run-time execution environment using bespoke Adapter software. During execution, XML is used to log data and events for subsequent analysis.

The conclusions from the work suggested that interoperability is promoted by the agreement at the Conceptual Modelling stage, and by having a common process framework and infrastructure. Reusability is enhanced by having model definitions which are independent of the simulation implementation, and scenario data which is separate from the models. Other benefits, in terms of modularity, extensibility, portability and quality, were also suggested. On the downside, there were concerns about being at the mercy of commercial tool providers, the steep learning curve (for M&S staff) to understand this new (software-engineering-based) approach, and the rigorous information management needed to ensure effective reuse and interoperability. Significantly, among the lessons learnt from the research, it was concluded that culture and mindset have a pivotal role to play in achieving the potential benefits that the proposed approach offers. Intended future work included the identification of constraints to be applied during Conceptual Modelling, to promote reuse and interoperability, and the development of a meta-modelling approach which would allow models to interact without prior knowledge of each other.

There was time for two questions following the presentation. First, the Session Chairman noted the wide use of Commercial-off-the-Shelf (COTS) tools for the work, and asked whether the project had any insurance against suppliers changing these unilaterally. Ms Harrison replied that there were several tools that could support each stage of the process framework, and that the choice that was made was deemed to be the most appropriate at the time the work was carried out. However, if any one selected tool was no longer suitable, there were several others that could be substituted; hence, the overall process-framework approach was robust to changes to COTS tools. Secondly, a German delegate commented that they were working in the same direction, and he would be presenting a paper on this at the next IITSEC conference in Orlando, USA. He then went on to ask a two-part question: had the project considered other approaches than DLLs for the modelling components, such as the Common Object Request Broker Architecture (CORBA); and how did the project handle documentation issues, such as a model's intended use and associated assumptions? In response to the first part of the question, Ms Harrison replied that they had performed a detailed analysis of various options for representing the model components, and that they had concluded that DLLs were most appropriate for their use. However, this was not definitive, and they were currently involved in some collaborative work with the Australians where they were considering using DCOM instead of DLLs. In response to the second part of the question, Ms Harrison replied that the models are fully defined during the Conceptual Modelling stage, in UML, and that this is automatically translated into XML for documentation purposes. Importantly, for reuse, it was most likely that tailoring would have to be done at the UML level, and then the DLL automatically produced from this; of course, it may be possible to use a DLL directly in some circumstances, but that this was not considered to be the norm.

Finally, another German delegate commented that the approach proposed here was very much in line with current thinking in Germany and NATO, and that the use of Conceptual Modelling above the object-oriented software engineering level was very important in establishing interoperability and allowing the physics of the modelling process to be concentrated upon.

Paper #12

Asymmetric Threats Modeling and Application of LINGO Language
Dr J. KARAKANEVA, G.S. Rakovski Defence & Staff College, Defence Advanced Research Institute, Sofia, BUL

This paper focussed on the proposed use of Game Theory to model the decision-making process in asymmetric threat scenarios, and the role of the LINGO language to facilitate the implementation of those models. Three Game Theory models were identified: antagonistic, bi-matrix, and coalition. The presentation concentrated upon antagonistic gaming, which is used to represent two directly-conflicting players, and bi-matrix gaming, where there may be two or more players who have conflicting objectives, but whose interactions are not strictly antagonistic. Using these theories, the decision-making process on each side of a conflict can be modelled by a planner who has a 'payoff' matrix, representing his own potential courses of action, together with those he perceives of his opponent. Theoretical analysis of this matrix allows the planner to determine the 'best' course of action using one of four pre-defined decision criteria: pessimism, optimism, least regret, and rationality. By implementing suitable game-theory models using the commercially-supported language LINGO, various experiments have been performed to compare simulation results with historical data, thus illustrating the overall utility of the approach. Further work is aimed at continuing game development from historical data, to find and apply optimal decision-making strategies within contemporary conflicts involving coalitions and trans-national organisations.

Following the presentation, the Session Chairman commented that the French had investigated this approach some years ago but had difficulties, partly because the models were difficult to extend, but mainly because the military customers found the theoretical underpinnings of the models somewhat opaque. Consequently, his question was: did you have the opportunity to apply this to a real problem with a real customer and, if so, what was the reaction? Dr Karakaneva did not answer the question directly, but commented that she worked in the operational research area of a military college, and the view there was that Game Theory was perceived to be important for improving the education of military decision-makers. Consequently, it was hoped that military officers educated in this way would be receptive to models based on this approach.

Unfortunately, further questioning was not possible because Dr Karakaneva suffered an accident whilst on stage, and had to withdraw temporarily; thankfully, she made a full recovery later. However, a Spanish delegate made a short comment in support of this game-theory approach. Although it was true that the military had difficulty in understanding the underlying mathematics, modern interactive simulation tools largely overcome this difficulty through excellent visualisation techniques, allowing the military to concentrate on selecting the underlying assumptions and parameters of the models. Also, he pointed out that this approach was not only suitable for wargaming, but can be used for acquisition and other defence-related activities.

Paper #13

Enhancing Interoperability Through Standard Procedures for Recording and Communicating Information on V&V Planning, Implementation and Results
Mr R.L. MAGUIRE, QinetiQ, Salisbury, UK

This paper outlined a new International Test Operation Procedure (ITOP) concerned with the Verification and Validation (V&V) of M&S. This ITOP is being developed by Working Group of Experts (WGE) 2.7 of the International Test and Evaluation Steering Committee (ITESC), set up by France, Germany, UK and USA. In general, ITOPs have been used as the basis for standard agreements (STANAGS) across the NATO community, and this particular V&V ITOP (reference ITOP: 1-1-002) is due for release in early 2003. Open distribution is only to Government Agencies of the four sponsoring nations, but other nations can obtain a copy (from Aberdeen in the USA), as long as there is no objection from the four nations.

The outline of the V&V ITOP covered the four primary concepts which underpin it. First, V&V information is documented under three separate *cases*, covering models, data and simulations, respectively. Secondly, explicit *claim arguments* are used to structure V&V evidence in support of M&S accreditation. Thirdly, the V&V of a product is characterised by the *impact level*, which identifies the severity of the outcome from misuse of the product, and the *effort level* that was required to establish the required degree of confidence in the product. Fourthly, a *logbook* is employed for recording V&V information, especially that associated with important assumptions about data, models and simulations.

Following the presentation, the Session Chairman asked a question regarding the possible production of a single Recommended Practices Guide (RPG) for VV&A, which would be applicable throughout the M&S community. He noted that the DoD has produced a VV&A RPG, of which Version 2 was available as a World Wide Web document, with individual viewing perspectives for different types of simulation and users. Similarly, the French had developed a RPG which was mainly directed towards the VV&A of HLA systems, and now this ITOP was being published, aimed at the V&V of M&S within the Test and Evaluation Community. He wondered if the speaker had any views on how we might move forward to a single STANAG covering this VV&A area. In response, Mr Maguire did not offer a direct solution to this difficult issue, but commented that 2 US members of WGE 2.7 had been involved in the production of the DoD's VV&A RPG, and that they had promoted its features during the development of the ITOP. Moreover, the main idea behind the ITOP was the recording of important M&S information, and that this was a general concept that was widely applicable and could be used within any RPG. He felt that the way forward was for M&S products to each carry their own VV&A logbook information in a central repository, to facilitate reuse. The Session Chairman thanked the speaker for this response, and agreed that the logbook concept was very important; however, he considered that this, in itself, would not result in a common set of VV&A procedures and practices, and that the M&S community needed to address this matter explicitly.

Paper #14

Combat Modeling by Using Simulation Components
Lt O. KULAÇ and LtJG M. GÚNAL, APGE ve Bilkardes Bsk.ligi, Ankara, TU

This paper, which was presented by Lt Gunal of the Turkish Navy, outlined a scheme for component reuse in M&S, and described the pilot use of this scheme in the development of a Turkish Navy Air Defence Model.

A language-independent (and paradigm-independent) approach was adopted for the component scheme, where each component is considered to have a syntactic interface and a semantic interface. The syntactic interface supports the sending and receiving of *properties*, which are data items, and *events*; the semantic interface defines how these properties and events are generated and processed. Components interact by sending and receiving properties and events, but the semantic coupling is loose in that a sending component has no knowledge of how its transmitted properties and events will be used by any other component. Importantly, the scheme also supports component aggregation by defining a *container* construct, which allows several components (and/or containers) to be composed into a higher-level component.

For the initial Air Defence Model application, the Java programming language was selected, together with a Java-based Geographical Information System (GIS). Each model component was designed using a Model/Viewer/Controller design pattern, and the final simulation was constructed using three containers: one to group the Defender components; one for the Attacker components; and one for the Target component. From the experience of this pilot application, it was concluded that the devised component scheme had provided flexibility and modularity in model building, with a faster design time. However, the authors considered that their research was still at an early stage, and that there was still much work to do in increasing the complexity and realism of the Air Defence Model application, and in testing and refining their component scheme for M&S.

Following the presentation there were two questions. First, the Session Chairman enquired as to the difference between an object-oriented and a component-based approach. Lt Gunal replied that the two were very similar in that components may be objects; the difference, however, is that components can be stand-alone, whereas objects are not. Secondly, a German delegate asked about the relationship between this work and HLA, noting that HLA, like object-orientation, was not the technology to provide a component-based approach on its own. Lt Gunal responded that HLA was not central to their research, but that their component-based approach can be adapted to HLA if required, and that they are currently looking at this.

Finally, the Session Chairman provided his summary of the discussion that had followed the presentation by commenting that, although HLA provides objects and classes, it does not support the full range of facilities that one normally associates with an object-oriented paradigm (such as class methods), and that this was quite deliberate. Furthermore, there is nothing inherently contradictory about HLA and component-based development, but that something extra has to be added above HLA to facilitate this, such as the scheme presented in this paper.

SESSION IV – DEVELOPING INFRASTRUCTURES AND ARCHITECTURES TO SUPPORT OPERATIONS AND ACQUISITIONS

Session Chair: Mr Andrew FAWKES, UK

Paper #15

Acquisition par la simulation du futur système de combat aéroterrestre /
Simulation-Based Acquisition of the Future Air-land Combat System
ICA D. LUZEAUX and IPA P. LODEON, DGA/STTC/SC, Paris Armées, FR

This paper was presented by Colonel Luzeaux, and was concerned with providing a qualitative analysis of the potential economic advantages of Simulation Based Acquisition (SBA) for complex system-of-systems procurements, which will form part of the new capability-led approach to Defence being employed by the French MOD. The context for this work is the Future Air-Land Combat System ("Bubble"), which was referred to in General Auroy's keynote speech, and in the questioning following Dr Kam's presentation in Session II. Importantly, this will be the French MOD's first system-of-systems acquisition programme, starting from scratch, and is intended to be a test bed for new acquisition approaches, such as SBA. The contract for the simulation to support this programme will be placed in Financial Year 2002, with delivery planned for mid-2004.

The thrust of the analysis provided by the presentation was that SBA was likely to add a 21% overhead to acquisition costs, but that this should be offset by cost reductions associated with risk reduction during the early phases of procurement, and with a reduction in cost drifts later in the cycle when unforeseen events occur (the later advantage accruing from the greater agility of a SBA process). Furthermore, by considering cost reductions in the SBA overheads resulting from reuse of M&S software across a family of projects in an acquisition programme, it was considered that SBA could result in non-negligible overall savings; typically, around 25% of all acquisition costs. From this postulated SBA saving, it was suggested that the operational benefits of a system-of-systems approach, employing Network Centric Warfare (NCW) concepts, were essentially free. Accordingly, the paper considered that SBA was a promising approach, and that experimental data should be collected to confirm this paper's qualitative economic analysis.

There were two questions from the floor, following the presentation. First, a delegate from the French Headquarters asked if this simulation-based approach, when validated, could be applied to other applications; for example, to achieve a minimum cost for a particular military operation. Colonel Luzeaux responded that this was a very difficult question to answer for the general case, but that their tool might be able to contribute to some aspect of this problem. Importantly, they have had discussions with the US, UK, Italy and Germany, with a view to pooling simulation tools, thus providing a cost-effective way of increasing the potential applicability of this SBA approach. Secondly, a US delegate noted that a key feature of SBA is the integration of M&S across the life-cycle, and wondered if the authors had given any thought to how the required cultural change might be brought about. Colonel Luzeaux replied that the success of SBA relied upon three lines of attack, which the French are engaged upon concurrently. First, suitable tools must be provided, as exemplified by Dr Kam's ITCS presentation in Session II. Secondly, acquisition processes must be changed, and he was currently engaged in this personally. Thirdly, there must be cultural change, which is the most difficult aspect. This is being addressed by ensuring that the highest level in the DGA has signed up to the approach, and by expending effort to convince national (industry) partners to participate fully (some remain sceptical and will take time to change).

Paper #16

Non-Hierarchical Approach to Couple CCIS with M&S
Dr H.-P. MENZLER and Mr M. SIEBER, WTD 81, Greding, GE

This paper, which was presented by Dr Menzler, provided a theoretical discussion of the issues associated with interfacing operational Command, Control and Information Systems (CCIS or C2IS) with modern simulations. From this foundation, a pragmatic interfacing scheme was then described, and the implementation of this for the US-German SINCE project was outlined.

The theoretical discussion of interfacing techniques was based upon a Common (Battlespace) Reference Model (CRM) from which both the C2IS and the M&S domains could inherit suitable representations. Using this CRM, a Proxy function could implement mappings between the two sets of representations, thus providing interoperability. However, no such CRM currently exists, and it was the presenter's view that this situation was unlikely to change. Therefore, a practical C2SIM-Proxy would be needed to map between existing C2IS reference models, such as LC2IEDM, and M&S representations, such as the HLA RPR-FOM. This was the approach adopted for Phase 1 of the SINCE project, which is currently in progress and is largely concerned with Decision Support and Test & Evaluation applications. Here, the NATO ATCCIS data model (now INFIS) is employed for the C2IS domain, and the M&S domain uses HLA with a CORBA-based RTI and a special *Ψ-SA* Reference FOM & middleware. A C2SIM-Proxy provides the mapping between the two domains, using CORBA as the communication mechanism. Additionally, there was a need to integrate other C2 functions, such as those associated with collaborative planning, which communicate via the (World Wide) Web, so the C2SIM-Proxy was extended to address this additional interfacing, essentially providing a three-port total-mapping function. Two further phases of SINCE are envisaged, running beyond 2006, hopefully with the involvement of other nations.

Following the presentation, there were two questions from the floor. First, a Canadian delegate wondered why an existing NATO C2 reference model, such as LC2IEDM, could not be adapted for the M&S community. Dr Menzler replied that it would probably be possible to make this work, but with a significant cost penalty. For example, there are practical problems in that LC2IEDM is a relational model and would need to become object-oriented to be compatible with M&S applications. Furthermore, LC2IEDM would need to be extended down in resolution in order to support M&S needs. Consequently, Dr Menzler felt that a loosely-coupled approach, where each domain had its own data model, with a C2SIM-Proxy providing the interfacing, was a more pragmatic and cost-effective approach. Secondly, a German delegate asked whether the provision of a Web-based interface to collaborative planning functions meant that planning would be done outside of the C2 systems. Dr Menzler replied that the collaborative planning tools were not logically separate from the C2 systems. The idea was that they would be coupled into the various C2 systems of participating nations, via a Web portal. This would allow a common set of planning tools to be used across all nations, regardless of the C2 systems employed.

Paper #17

Perspectives on the Use of M&S to Support Systems Acquisition

Dr J. DAHMANN*, Mr Z. FURNESS*, Dr S. KISSIN** and Dr S. STARR*, *The MITRE Corporation, McLean VA, **PEO Metrics, Arlington, VA, USA

This paper was presented by Dr Starr, and reported upon recent work by the authors in support of the US DoD's initiative into Simulation Based Acquisition (SBA). The paper started by presenting the trends affecting DoD's acquisition needs, which provide the motivation for SBA and the context in which it must evolve. It then went on to provide a briefing on two significant and recent DoD activities: a National Research Council (NRC) study into the next-generation M&S capabilities required to support enhanced defence systems acquisition, which reported in Summer 2002; and an Office of the Secretary for Defense (OSD) Workshop, held in April 2002, which was to provide input to an investment plan for M&S, to support the acquisition and transformation of C4ISR[8] systems.

In keeping with the discussions following Colonel Luzeaux's presentation, earlier in this session, the recommendations of the NRC study addressed the issues of: Infrastructure for M&S (i.e. tools); Use of M&S (i.e. process); and Culture and People. Significantly, it also offered recommendations under a fourth category of Technology and Research, in order to enhance the science and technology base for SBA. Among the topics raised here was the need to improve the ability to deal with system-of systems issues, and to exploit academic expertise by the creation of a research initiative at multiple universities.

In contrast to the NRC study, which dealt with the whole of Defence, the OSD Workshop was focussed specifically on the C2 area. The recommendations of the Workshop addressed: Policy and Management Process; Environment and M&S Products; Measures of Merit (i.e. measures of system performance linked to measures of mission effectiveness); and Support Tools and Foundation Data & Information. Most importantly, it was concluded that these required changes would only be successful if they were accompanied by a change in attitude and culture.

In summary, Dr Starr commented that, in order to support the acquisition of future DoD systems, cultural change is essential, a system-of-systems perspective is vital, a strong and integrated M&S capability is required, and a balanced set of M&S initiatives, covering policy down to foundation data, must be pursued.

Following the presentation, a Canadian delegate suggested the need for a new language to describe the system-of systems ideas that are central to modern acquisition thinking. He reported that the Canadians have developed a new set of terms based upon Operational Functions, to move discussion away from equipment systems towards military capability. He asked the presenter if he agreed with this approach. Dr Starr replied that this was a very good idea, and he applauded this Canadian initiative.

Paper #18

Polish Federation of Land Battle in a Distributed Interactive Environment

Col. A. NAJGEBAUER, LtMSc D. PIERZCHALA and LtMSc J. RULKA, Military University of Technology, Warsaw, PL

This paper was presented by Colonel Najgebauer, and provided a very full and detailed account of the development of a prototype HLA federation for Computer Assisted Exercises (CAX) in the Land

[8] Command, Control, Computers, Communications, Intelligence, Surveillance and Reconnaissance

environment. The work formed part of the concepts phase of a procurement, by the Polish MoD, for an operational CAX facility for the Land Battle. Following the successful development of its prototype, which revealed an open system design that could easily be adapted and improved, the Polish Military University of Technology has now won the contract, under competition, to deliver the operational CAX facility.

The algorithmic nature of the prototype was designed using strongly-mathematical approaches, including game theory, and the development followed the HLA FEDEP. Importantly, it was noted that Step 4 of the FEDEP, Develop Federation, was sparsely populated and needed to be augmented by some well-defined software/systems engineering approach. For this reason, the project adopted the Rational Development Process (RUP), together with the Rational Rose toolset that supports the (object-oriented) Unified Modeling Language (UML). The consequence of this was that the Federation Object Model (FOM) was extended with the UML notation.

When exercising the prototype HLA federation, certain interoperability problems were experienced. These were at the semantic level, where different federates had inconsistent views, for example in losses assessment and terrain granularity, and reflects the fact that HLA only addresses the syntactic aspects of interoperability, and not the semantics of simulation behaviour (a known limitation). Interestingly, the completed prototype federation was subjected to a detailed set of experiments, to reveal its external characteristics, such as relative difference between final losses and required losses, and internal characteristics, such as the initialisation time of federates. From these results, the suitability of the proposed approaches could be assessed, to guide federation developers and users.

There was time for one question, which was from a UK delegate who asked how timing synchronisation problems between disparate federate objects might be addressed. Colonel Najgebauer replied that procedures were available to address this in the HLA Run Time Infrastructure (RTI) employed[9], and that they had used a conservative time-constrained approach to achieve the required synchronisation.

SESSION V – DEVELOPING CO-OPERATION BETWEEN NATIONS & PFP

Session Chair: Ms Lana McGLYNN, USA

Paper #19

Partnership to Establish the Republic of Uzbekistan Special Center for Modeling and Simulation (SCMS) and National M&S Infrastructure

LtC R. RAKHMATULLAEV*, Capt. N. TURSUNOV*, Mr H. THOMPSON** and
Mr J. WRIGLEY***, *Modeling, Simulation & Informatics of Academy of AF RU,
Tashkent, UZ, **MSIAC, Vidalia, GA, USA, ***MSIAC, Alexandria, VA, USA

This paper, which was presented by Mr Thompson, provided an extensive description of a collaborative project between the US and Uzbekistan Governments, whose long-term goal is to provide Uzbekistan with a self-sustaining M&S and Advanced Distributed Learning (ADL) capability. The project is jointly funded by the US Government, under its Foreign Military Funding (FMF) programme, and the Uzbekistan Government. It is managed by the Modeling and Simulation Information Analysis Center (MSIAC), which is a US Government-owned, contractor-operated organisation, and draws upon the expertise of other US DoD organisations, including STRICOM, JFCOM and the Naval Postgraduate School. The overall approach of the project is to train and educate Uzbeks to be able to conduct M&S and ADL activities using their own equipment and people. Although most of the activities will take place in

[9] RTI 1.3 Version 4

Uzbekistan, in some cases Uzbek staff will travel to the USA, in order to receive special training, such as in the management of simulation centres.

The project is the vision of the Uzbekistan Minister of Defence, and dates back to October 2000, when Uzbek officials visited the USA. It is due to extend beyond 2008, with a major milestone occurring in May 2003, when the building for a new Special Centre for M&S (SCMS), at the Uzbekistan Armed Forces Academy, will be completed. The first two-year phase of the project (2001-2002) has involved planning and preparatory work, and subsequent implementation of these plans is based upon an evolutionary model with four identified phases ranging from initial start-up through to enhanced-operational modes. Notable achievements in the planning phase include: the establishment of a Concept Overview and Strategic Plan; the definition of the SCMS; the creation of Simulation Center Information Exchange Program (SCIEP) with appropriate sources in the USA; the production of a M&S and ADL Master Plan for Uzbekistan, with an attendant Implementation Plan and Acquisition Strategy; and the securing of FMF programme sponsorship from the USA.

To date, the project has been highly successful in taking Uzbekistan forward from a starting position of zero capability, in a very short time. This success is attributed to (among others): a strong commitment from the Uzbeks, from the President down; the establishment of a US-Uzbekistan M&S Working Group, which treated strategic planning as an educational process, and provided continuity of approach; the early definition of requirements; and the availability of US expertise, funding and support.

Paper #20

South Eastern Europe Cooperation in the Field of Modeling and Simulation
Prof. S. DESKOVSKI, Dr Z. GACOVSKI and M.Sc. S. ANGELEVSKI, Military Academy
“General Mihailo Apostolski”, Skopje, Former Yugoslavian Republic of Macedonia (FYROM)

This paper was presented by Major Angelesvski, and provided the rationale for the co-operative use of M&S by the countries of South Eastern Europe (SEE), together with an outline of some recent activities in this field.

The nine SEE countries are in a transitional period, and need to promote mutual confidence in defence and security, in order to achieve regional military co-operation and PfP. The Southeast European Defense Ministerial (SEDM) process and the SEE Brigade (SEEBRIG) are examples of progress towards this goal. Common military education and training is seen as the way forward to achieve new military professionalism, interoperability and integration, and the long-range vision is to create an Advanced Distributed Learning (ADL) and M&S environment, available to all SEE countries. Furthermore, by basing such an environment upon NATO procedures and standards, this will support the integration of aspiring SEE countries into NATO.

Two practical examples were given of M&S related activities between the SEE countries. First, the Southeast Europe Simulation (SEESIM) Exercise was outlined. This was hosted by Greece in 2002, and allowed the SEE countries to exercise (among others): national civil-military emergency procedures; each SEDM nation’s ability to plan and provide assistance to other nations in the region; and the SEEBRIG Headquarters. The next exercise will be held in Turkey in 2004. Secondly, the 1st Explosive Materials, Weapons and Military Technology (EMWMT), held in Macedonia during September 2002, was outlined. This drew good support from regional authors, as well as global contributors, and contained several papers closely related to the M&S field, particularly in the application areas of missile and fire-control systems, simulators and training equipment, and ballistics.

General conclusions from the paper confirmed the importance of M&S in achieving regional co-operation and common training, in order to realise the goal of a lasting peace for the region, and to help nations capitalise on accumulated experience in addressing security risks. The SEESIM Exercise and the 1st EMWMT Symposium provided good examples of progress, to date.

Paper #21

The Enterprise Team: The United States Modeling and Simulation Collaboration Assistance Effort – A U.S. Program to Improve Interoperability in Support of Global Networking, Modeling and Simulation, and Peace Support Initiatives

Mr J. DANIELE*, Mr J. WRIGLEY**, Mr H. THOMPSON**, Mr D. COLLINS***, Mr N. MORGAN****, Mr S. LAUSMAN*****, *STRICOM, Orlando, Fl, **MSIAC, Alexandria, VA, ***JWFC, Suffolk, VA, ****NAVAIR, Orlando, Fl ****USAF ESC, Hanscom AFB, MA, USA

This paper, which was presented by Mr Wrigley, provided an overview of the composition and approach of a M&S collaborative 'Enterprise Team' formed from five US DoD agencies: the Joint Forces Command/Joint Warfighting Center (JFCOM/JWC); the Naval Air Warfare Center Training Systems Division (NAWCTSD); the Air Force/Electronics Systems Command (AF/ESC); the Modeling and Simulation Information Analysis Center (MSIAC); and the Program Executive Office – Simulation Training and Instrumentation (PEO-STI).

The goal of the Enterprise Team is to optimise investments, reduce overlap and avoid redundancy, in order to execute effectively M&S programmes in support of US national security policies and objectives. Each team member contributes particular expertise: JFCOM/JWC provides the lead in Advanced Distributed Learning (ADL) and Regional Engagement Networks; NAWCTSD provides specialist support in the area of Enhanced International Peacekeeping Capabilities; AF/ESC provides emerging democracies of central/eastern Europe with low-cost, highly-capable National Crisis Management Centres; MSIAC leads on M&S Education, Planning, Employment and Assessment; and PEO-STI provides constructive simulations for local or distributed Computer Assisted Exercises (CAX).

Members of the Team meet regularly so that they can speak with one voice while addressing international peacekeeping & warfighting training, and operational requirements. Consequently, if a foreign Government contacts any one member of the Team, then synchronisation with the other members will be automatic. This eases the burden on nations seeking US assistance in the M&S and ADL fields. Moreover, the Team is able, collectively, to exploit US funding streams and multiple programmes on behalf of foreign nations, and define and integrate requirements. Importantly, the Team employs common equipment specifications, which eases the integration of their components when establishing M&S/ADL facilities in foreign countries, thus providing greater cost-effectiveness and system robustness.

Following the presentation, there was one question from the delegate who presented the previous paper (from the FYROM). He asked whether it would be possible to link software applications between different M&S centres provided by the Enterprise Team; for example, between centres in different countries. Mr Wrigley replied that they have designed their systems so that they can be integrated, whether these be in the same region, or on a global scale. This is one of the advantages of using a common set of equipment specifications across the Team. However, such integration would only be possible if the appropriate communication facilities were available within the countries concerned.

Paper #22

European Industrial Co-operation

Kol. J. J. DE DIE, RNLA/DM/C3I/STS, The Hague, NE

This was an invited talk that was originally scheduled for the previous day, but was delayed because Colonel de Die had been required in Germany on business. The talk was centred upon the research and development activities of the Common European Priority Area (CEPA) 11, which is concerned with M&S, and involves collaboration between various European nations and their industries. The background to CEPA 11 was explained, together with an outline of two of its collaborative projects.

In order to pool their Defence research and development activities, 15 European nations collaborate to form the West European Armaments Group (WEAG). Under this WEAG, there is the West European Armaments Organisation (WEAO) Research Cell, in Brussels, which is responsible for organising 13 CEPAs; for example CEPA 1 is associated with Radar, and CEPA 11 is concerned with M&S. Significantly, 14 (of the 15 WEAG) nations are represented on the CEPA 11 Steering Committee, which is chaired by Colonel de Die. The overall aim of CEPA 11 is to develop, establish, maintain and improve an advanced technology base for European Defence M&S, and a primary goal is to achieve this by stimulating Defence industries and encouraging Industry/Government collaboration. CEPA 11 activities include projects to advance the infrastructure, architecture, tools and processes for M&S, particularly with regard to the reuse of M&S. The development of working demonstrators is seen as a key way forward in this endeavour.

Funding of CEPA projects, involving both Industry and Governments, comes from one of two schemes: EUCLID, which is driven by the requirements of Governments, and EUROFINDER, which allows industries (from at least two nations) to propose projects. All projects have to be approved by the top-level of the WEAG; EUCLID projects are funded two-thirds by the participating nations, and one-third by industry; EUROFINDER is funded half by the participating nations, and half by industry. Importantly, no Government money crosses national boundaries; each participating nation funds its own industry, which means that if a nation does not have a suitable industry, then it cannot participate in a project. This is often viewed as a limitation of the schemes.

The current CEPA 11 research topics are: Methodologies; Low Cost Simulators; Simulation Based Acquisition; Verification, Validation and Accreditation; Embedded Training; Synthetic Forces; and Networked Simulations. The two representative projects, which were outlined by Colonel de Die, were RTP[10] 11.12 and RTP 11.13, both of which are aimed at producing practical demonstrators, and have evolved from previous study projects. RTP 11.12 is led by Germany, and involves Italy, Portugal, Turkey, and the Netherlands. It is concerned with providing an advanced simulation capability to a dedicated (AerMacchi) aircraft, which will allow it to engage in a simulated land battle (e.g. in the desert) while actually flying over another area (e.g. the sea). This significantly improves the flexibility of pilot training and mission rehearsal, and a live demonstration in Italy is planned for May 2003. In contrast to RTP 11.12, RTP 11.13 is a much larger project, involving 13 Governments and 23 industrial partners, and totalling 17m euros. Its aim is to produce a secure pan-European repository of reusable simulation models from which HLA federations can be built. The project, whose lead nation is the UK and lead industry is THALES (UK), is due for completion in October 2003. Importantly, it has produced a Synthetic Environment Development Environment (SEDE) Conceptual Framework, which is based upon the HLA FEDEP, and employs a pan-process SE Management Tool and common Model Repository, in order to facilitate reuse.

In conclusion, Colonel de Die considered that CEPA 11 had been successful in pursuing its overall aims, and stressed the importance of M&S standards for ensuring future success in this area.

CLOSING REMARKS

Programme Committee Chairman, Mr G BURROWS, Head, NMSCO, UK

Mr Burrows thanked all session chairmen for their efforts in keeping the conference on track and running smoothly. He also thanked the presenters for their efforts both in preparing and giving the various papers,

[10] Research Technology Project

which he considered were an excellent set. Finally, he thanked the conference delegates for their participation during questioning, and for their good humour throughout, which he felt contributed to the overall success of the event. He then went on to summarise some key points from the Conference, which had been initially provided by the Technical Evaluator for the Conference, Professor Mike Moulding, and augmented with some of his own observations. These were presented under the categories of Models, Applications and Process.

In terms of issues related to Models, the Conference had shown that there was an increasing requirement to address non-physical aspects, such as people, organisations and doctrine. Interoperability between people (as well as equipment), and the representation of military decision processes and asymmetric threats, were examples of this. Another issue relating to modelling was the need to cope with the 'system-of-systems' thinking that is associated with a military-capability approach to acquisition. In particular, this would require models to be composed vertically as well as horizontally, and the provision of tools to support this type of integration.

Regarding Applications, papers during the Conference had highlighted increasing activities in two main areas: C4ISR/NCW[11] and SeBA/SBA[12]. First, the C4ISR/NCW area will place increasing emphasis upon interfacing operational C4ISR systems to M&S, and this is the focus for the next NATO M&S Conference to be held in Turkey in approximately one year's time. Secondly, the increasing role of SeBA/SBA within Defence organisations will require the interfacing of M&S across the entire acquisition life-cycle, and associated knowledge management and ownership issues will also need to be resolved.

Concerning Process issues, it was clear from the Conference that reusability of M&S (which is of paramount importance for improving cost-effectiveness) stems from reuse at the Conceptual Modelling phase, so standards must be developed for this. Moreover, validation of M&S demands that the suitability of the abstractions that are selected for our models are explicitly questioned; therefore, a higher-level phase above conceptual modelling will be needed, in order to understand the application domain in which our models will be used. Furthermore, the Conference had highlighted the need for cultural transformation, to enable the process changes associated with SeBA/SBA and M&S sharing & reuse, and this must be explicitly addressed if these initiatives are to be successful.

Finally, Mr Burrows thanked a number of key personnel, who had provided essential support to the Conference: the Interpreters who coped extremely well with the variety of accents and speeds of delivery; the French hosts who provided the excellent facilities; the charming French hostesses; the technicians who ensured the correct functioning of the audio-visual equipment; and his own NMSCO team. Mr Burrows then wished everybody a safe journey home, and closed the Conference.

[11] Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance / Network Centric Warfare

[12] Synthetic Environment Based Acquisition / Simulation Based Acquisition

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Introduction

Mr. G.J. BURROWS
Head, Modelling and Simulation Coordination
Research and Technology Agency
BP 25
92201 Neuilly-sur-Seine Cedex
FRANCE

I am Graham Burrows (Head of the NATO RTA Modelling and Simulation Co-ordination Office).

I have the honour and privilege to be the Chairman of the Conference Committee of this, the 3rd NATO Modelling and Simulation Group Conference. The Theme of this years Conference is "NATO-PfP/ Industry/National Modelling and Simulation Partnerships". For M&S activities to be successfully implemented it requires the setting up, at an early stage, partnerships and understandings between NATO, our Partners, Industry and National organisations. This Conference will address the interrelationships between these organisations, present some of the lessons learned and will also suggest future partnerships that could be established. I am sure you will find the Conference interesting and stimulating and worthy of the high standard and reputation that this Conference has engendered. Again, this year the Conference has attracted a high number of high quality papers – almost twice the number that we could accommodate in the time available. This has presented somewhat of a challenge to the Conference Committee – but I am pleased to say that the Committee enjoys a few challenges and this they took in their stride.

I would like to thank the Conference Committee for their help and support. You will find all their names listed in the Programme Announcement. I will briefly ask the Conference Session Chairs to stand up so that the individual Presenters may later make contact with their Session Chairs – provide them with a CV and also make sure their slides have been loaded onto the main computer. So – Erich Schwan; Hans Jense; Alain Dunaud; Jean-Louis Igarza; Andy Fawkes; Lana McGlynn.

I would also like to introduce Prof Mike Moulding. Prof Mike Moulding is a professor at Cranfield University, at the Royal Military College of Science at Shrivenham, UK. He has been very active in M&S for many years and has made great contributions particularly in the V,V and A field. Mike has agreed to perform a very useful function at our Conference that of the Technical Evaluator. Mike will provide a critique of each of the papers, the conference overall and the subsequent discussion. This evaluation will be included in the Conference CD/Proceedings.

Finally, I would like to offer my sincere and grateful thanks to our French hosts for providing these excellent facilities, their superb overall support.

Enjoy the Conference, in particular the Papers, please also make use of the breaks for side discussions, and enjoy the Conference Dinner – it promises to be a splendid evening at the Restaurant Le Procope – reputed to be the oldest Restaurant in Paris – and above all – enjoy Paris – You are here in a beautiful city at a particularly attractive autumn period – I hope the weather will be kind to you.

Address given at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

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Welcome Address

ICA Alain DUNAUD
DGA/DSP/SASF
26, Boulevard Victor
00460 Armées
FRANCE

Messieurs les Présidents, Messieurs les Officiers généraux, Mesdames, Messieurs,

Je suis heureux de vous accueillir ici à Paris, au nom de la France et du Ministère de la défense français, dans cet amphithéâtre Charles Renard de la délégation générale pour l'armement.

Si j'insiste sur le nom de Charles Renard, c'est pour indiquer l'attachement de la France, du Ministère de la défense et de la délégation générale pour l'armement à la maîtrise et l'utilisation de l'innovation technologique. Ingénieur militaire français (1847, 1905), il construisit un ballon dirigeable, premier appareil à accomplir un circuit fermé. Il est donc l'un des pionniers des débuts de l'aéronautique. Il est également l'inventeur d'une série de nombres encore utilisés pour la normalisation mécanique, la *série de Renard* dont la raison (ratio) est la *racine cinquième de dix*.

A l'époque, Charles Renard ne connaissait pas les techniques de simulation, et il était donc obligé de recourir à des maquettes et à des prototypes quand il voulait vérifier la validité de ses calculs et expérimenter ses inventions.

Et ceci illustre bien pourquoi nous sommes très intéressés par l'utilisation de ces techniques de simulation :

- Ce sont des outils essentiels pour aider à exprimer le besoin opérationnel, le besoin des forces armées. Le recours aux démonstrateurs fondés sur les techniques de simulation permet en effet de valider, avant les réalisations matérielles, le fait que le système envisagé sera capable de répondre aux performances qui sont attendues de lui.
- Ce sont également des outils qui permettent d'optimiser des ensembles de système, ou systèmes de systèmes, en adaptant les performances individuelles de chacun des systèmes à la satisfaction de la performance d'ensemble

Je n'insisterai pas plus sur ces points, qui seront abondamment évoqués lors de ces deux jours.

Je vous souhaite donc, je nous souhaite donc, un séminaire fructueux et productif.

Discours prononcé lors de la Conférence NMSG RTO sur « Les partenariats NATO-PfP/Industrie/Nations dans le domaine de la modélisation », organisée à Paris, en France, les 24 et 25 octobre 2002, et publiée dans RTO-MP-094.

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NATO Transformation – Implications for NATO Modeling and Simulation

RADM Dick Gallagher
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Supreme Allied Command Atlantic
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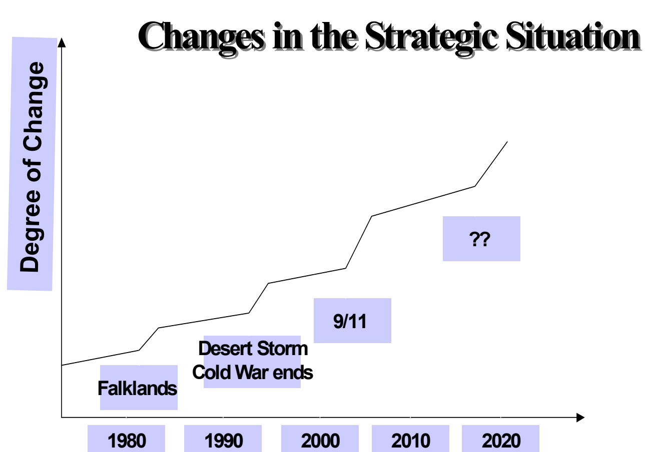
Norfolk, VA 23551-2490
USA

I am pleased to speak to you today on the subject of NATO Transformation and its implications on modeling and simulation.

Over the past few months, both Strategic Commands have been examining how the military side of the Alliance should adapt to the changing strategic situation, both organisationally and in terms of the operational capabilities we need.

As this is probably new territory for most of you and as it may have a knock-on effect on the way we provide guidance and support, I thought it would be useful to explain what we mean by transformation and where we are in the process.

One way to consider the nature of transformation and how it is stimulated, is to examine history. Generally speaking, significant changes in the way in which Alliance nations do business and acquire capability have arisen in response to a step change in the strategic situation.



For example, the Falklands War illustrated that crises could occur rapidly in distant places and nations may need to respond individually. Desert Storm showed that we need to consider coalitions of Alliance nations and others outside the traditional NATO framework. The end of the Cold War made us re-assess the balance of power in Europe and 9/11 expanded our thinking about asymmetric threats and the meaning of Article 5.

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

In each case, nations had to re-assess the state of their military capability and ways in which they would need to transform to meet new types of crisis.

In our recent work, we are endeavoring to transform in anticipation of world events, not as a reaction to them. Consequently, we are seeking to establish an organization, procedures and capabilities that are robust and able to respond to a wide variety of potential crises.

Returning to the time line shown here, what could be the next sea of change? Crises concerning Caspian Sea oil and gas? Confrontations in the Pacific? Further nuclear proliferation? Radical regimes appearing in regions vital to Alliance nations?

With this in mind, what are the recent changes that have caused another step change in our thinking?

A number of them are listed below and I am sure they are very familiar to most of you.

- Need to combat terrorism worldwide
- New relationship with Russia
- Reduced conventional threat to NATO area
- Asymmetric Threats
- NATO Expansion
- Increased Globalisation
- Growing capability gaps between Alliance members

We should also not forget that the Alliance is involved in a number of operations and initiatives that are likely to continue for some time, as shown here.

- Peace Support (Bosnia, Kosovo)
- Protection of Vital Interests (Oil traffic)
- Continued engagement with Partner nations
- Continuing engagement with other organizations (UN, EU, OSCE)

What are the implications for the Alliance of these new strategic issues and the continuing activities I mentioned?

Articles 5 and 6 of the Treaty, which were written to cover the collective defence of NATO territory and forces located therein, have taken on a whole new meaning. A new debate has ensued concerning the validity of pre-emptive action by Alliance members outside the NATO area to prevent possible attacks by terrorists and/or nations.

The Alliance is beginning to think more globally, driven partly by an increase in the global interests of nations, and partly by the global nature of the threat. Military responses demand higher mobility and the ability to operate over long lines of communication without the guarantee of local host nation support.

Threats are less easy to define and dealing with them raises a number of legal, political and economic difficulties that are not typical of conventional warfare – asymmetric threats lead to increased emphasis on, for example, computer security and the harmonisation of military and civil processes.

In response to these risks, new concepts will need to be developed together with the associated doctrine, plans, training and organisational changes.

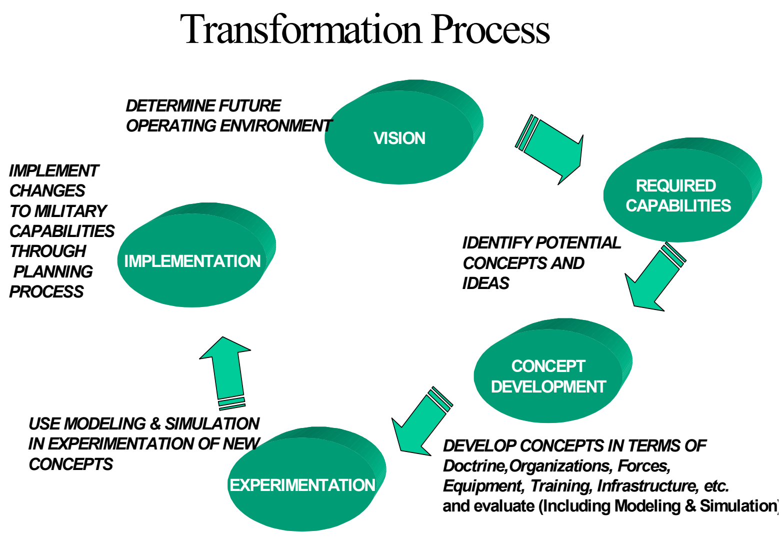
NATO structures will need to be more flexible in size and capability and incorporate a more joint and multinational perspective at all command levels. For example, the ongoing NATO Command Arrangements Review Process has incorporated the idea that we need one operational and one functional strategic command in the Alliance and work is also underway on the Minimum Military Requirements for such a command structure.

There are numerous definitions of transformation around and here is a shortened version with some amplifying points.

From an operational perspective, it is a process to accelerate improvements in military capability that are needed to combat significant changes in the strategic situation that have recently occurred or have a high chance of occurring in the future.

In order to bring about these changes, the NATO organisation itself will have to transform and thus organisational change is also part of the process.

From within the Strategic Commands, we have a number of avenues for bringing about a transformation in operational capability as illustrated in this picture.



We need to work with nations on their vision of the future crises and identify capabilities that will be required to meet them. These capability needs can be prioritised and communicated to nations through the defence planning process or new defence capability initiatives.

In certain cases, NATO staff and agencies will identify potential solutions in the form of concepts that can be developed and experimented with in a collaborative manner, including, of course, the application of Modeling and Simulation. This concept work could involve the development of prototype equipment, and/or doctrine, training, infrastructure improvement.

Implementation will still, for the most part, require nations to pick up the results and initiate acquisition processes, except for capabilities that are acquired through common funding.

Over the past few months, NATO staffs have been articulating a vision in terms of revised intelligence assessments, the level of ambition for future operations involving the forces of NATO members, and changes to the force structure.

Requirements are being developed in terms of capability improvements that are needed in the short, medium and long-term, where long-term is 2010 and beyond.

New concepts are being described and developed, including a concept for combating terrorism and other items as such-Initial Entry, Combat Identification, Reception & Onward Movement, Advanced Distributed Learning, Distributed Training & Simulation.

Some of which are being pursued under the NATO Concept Development and Experimentation process, while others are being considered within nations and the NATO Research Bodies.

Down the road, we will be involved in other aspects of transformation, as harmonising planning, priorities for critical capabilities and structural re-organization.

It is important that we pursue all aspects of a particular capability improvement in parallel – there is no point in fielding hardware if the doctrine, procedures, C2, logistics support, etc have not been developed and funded.

We are working with the NATO staff in Brussels on a new, reduced set of capability initiatives in time for the Prague Summit which is intended to focus, for the short and medium term, on a small set of achievable high priority needs.

Finally, as I mentioned earlier, both Strategic Commands are considering internal transformation and a better apportionment of strategic responsibilities that reduces duplication and is more compatible with future needs.

As part of this effort, at SACLANT we are exploring methods for closer links with the US Joint Forces Command to ensure that US and NATO transformation efforts are complementary and mutually beneficial.

In order to illustrate what this could all mean for the modeling and simulation world, I have chosen four areas, Analysis of Military Capability Needs, Concept Development and Experimentation and Operational Training and Exercises, where this capability will become increasingly important to NATO transformation.

Starting first with the analysis that is conducted to identify NATO's military capability needs. This work involves the assessment of NATO capabilities in representative scenarios such that gaps in this capability can be identified.

To do this work we need models that address the new situations that could confront us and methods for comparing various response options that NATO might take.

These situations involve traditional combat, but also peace keeping, information operations and the military contribution to managing the consequences of terrorist attacks.

Models should reflect the fact that we are becoming more joint and interoperable with various military and civil bodies in various NATO and non-NATO nations.

Having identified capability areas that require attention, we need to develop concepts that address these capability gaps.

In this case, M&S support is needed to evaluate these concepts, including the ability to measure the impact of the emerging technologies.

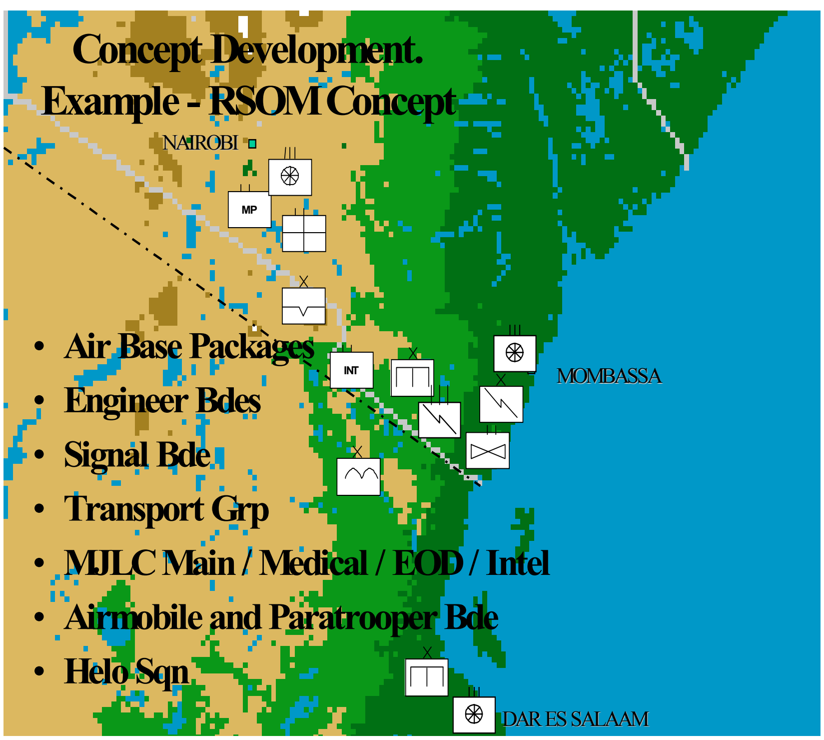
One area that is particularly important is the application of M&S tools for the analysis of decision making processes in multinational joint operations.

Finally, we are recognising that some parts of the military capability spectrum are harder to simulate than others. For example, we have extensive M&S capability in support of logistics concepts but very little when it comes to information operations.

To illustrate how M&S has been used to support the development of a logistics concept, I will briefly describe the ongoing "Reception & Onward Movement" concept.

Our analysis of a number of scenarios has shown that, in addition to needing more lift, NATO operations need a coherent, collaborative RSOM capability.

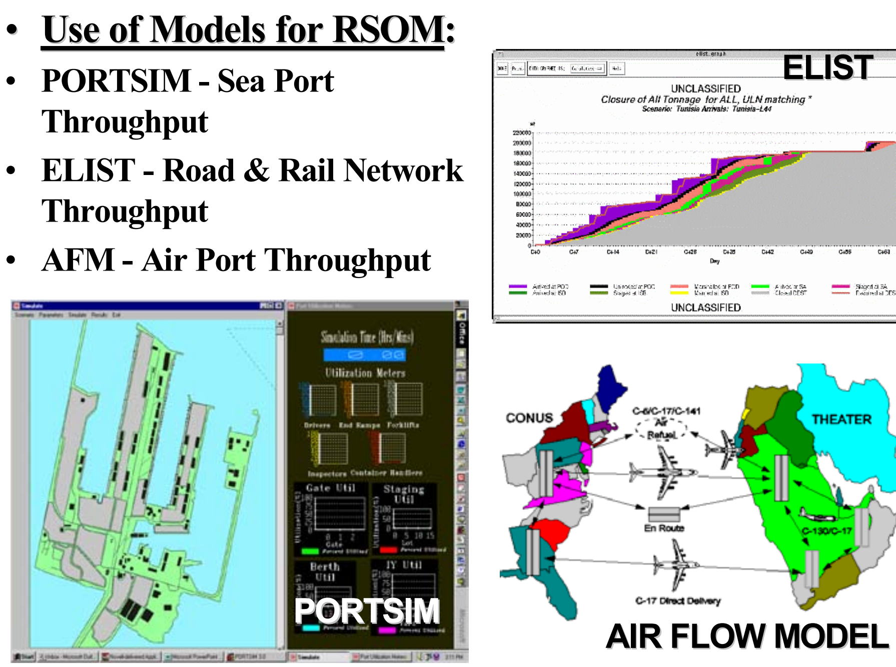
You see here an illustrative peace support scenario with the army formations that need to be moved forward and, on the left, the RSOM capabilities that would be needed.



In addition to resources, we have also come to understand that joint doctrine is required. For example, the Rear Area command and control arrangements need to be in sync with the national responsibility of moving forces into theater up until Transfer of Authority is established.

In order to develop the RSOM concept, we held a Mobility Seminar and supported it with extensive modeling capabilities from NATO and nations.

You see here examples of models from a particular nation that worked with the NATO model Allied Deployment and Movement System (ADAMS). These models simulate and analyze the flow of cargo and troops through ports and onward to the final destination.

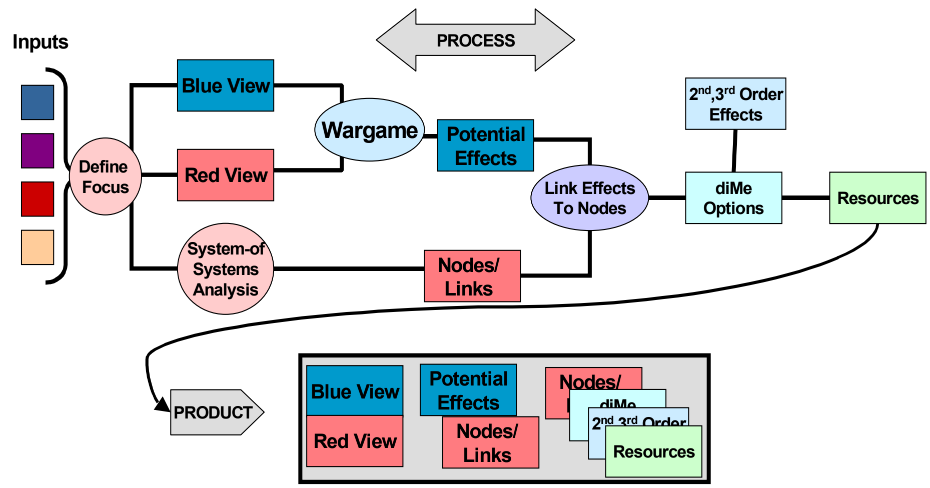


In this way we can investigate the merits of various solutions to the RSOM problem and validate the concept that is eventually developed.

Modeling and simulation has also an important role in the experimentation process. In the RSOM example, we are considering a practical examination of the concept in a real-world exercise. Experiments of this kind require additional M&S capabilities.

A recent example of the value of M&S in this area was the recently completed US Millennium Challenge experiment.

Concept Experimentation
Example - Millennium Challenge



Operational Net Assessment Process

This slide represents the Operational Net Assessment activity conducted as part of the US Millennium Challenge experiment. ONA assists decision makers in focusing their capabilities when, where, and how needed to generate decisive effects. Naturally this needs to be conducted prior to an actual crisis. That is a key point – this process represents a significant amount of focused analysis and synthesis of large amounts of information to turn our understanding of our selves, the adversary and the environment into actionable knowledge.

War gaming provided a list of potential effects based on Blue and RED objectives and their decisions. After Action Reviews based on the M&S outputs identified relationships, dependencies, strengths and vulnerabilities within and across systems.

In my final example, it is clear that training and exercises will play a major role in future efforts to transform NATO capabilities.

In this context, we need a complementary set of M&S tools.

These tools include an advanced distributed learning capability to train the augmentees before the exercise such that they are ready to assume their responsibilities effectively. We need to educate and train them anytime, anywhere as needed.

The tools used to support training and exercise events should be reusable and interoperable to cut down on the modeling cost, as they should be multi-resolution to optimise their use at different levels of operations.

The real world operational CCIS systems should become the backbone of these simulations. Embedded decision making tools could make them valuable during real operations.

In summary, it is clear to all of us that the strategic situation has changed for NATO as an organization and nations individually. As a consequence, NATO is beginning to transform both organizationally and in terms of capabilities.

This transformation will need to be managed to avoid the proliferation of independent, uncoordinated improvement actions that are wasteful and counter-productive. This is one reason for the proposal to adapt our command structure such that transformation becomes the primary responsibility of one Strategic Command.

It will not be a quick fix – indeed one could say that transformation in a coherent manner is a continuing process.

We also recognise that capability improvement is not just about materiel. It also involves re-assessment of the way we develop requirements, prioritise needs, develop doctrine, and conduct training.

Finally, it is already apparent that Modeling & Simulation will grow in importance as it is a key tool in the transformation process. Consequently it is extremely important that NATO is supported by M&S capability that meets all our needs. In this regard I would ask you to consider the points shown here:

- To what extent should NATO nations rely on the capabilities (networks, models) of individual nations versus establishing a common funded NATO M&S capability?
- To what extent can each of the 4 areas I mentioned (Analysis, CDE, Training and Exercises) be supported by a common NATO backbone and model architecture?
- Do we need a NATO Simulation Centre?
- Can the CDE process itself be used to resolve these issues?

Views of the French Industry in Modelling and Simulation

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INTRODUCTION

The modelling and simulation or M&S has experienced a dramatic evolution over the recent years, evolution pulled by new operational needs and made possible by the fast progress of the computer industry.

The domains of application of the M&S remain the same as previously, namely the fighter training, the operational analysis and the support to the development of weapon systems. However, inside each of these domains of application the use of M&S has considerably increased leading to a radical change of certain processes, in particular the process of acquisition. The industry has had to adapt itself to this new situation and even to anticipate it.

THE DOMAINS OF APPLICATION OF THE M&S

The Fighter Training

In the past, not such a long time ago, training was exclusively individual and focused on the knowledge of the vehicle and its operations and on psychomotor aspects, that is the acquisition of the reflex behaviours necessary for the piloting or driving of the said vehicle. In this context, the realism of the physical environment was essential : high fidelity of the cockpit as well as of the sensory cues, vision, sound and kinestesic effects.

The tactical environment was rudimentary, often limited to a target piloted by the instructor and the natural environment was almost non-existent. Furthermore there was little integration of the vehicle into the system of force to which it belonged, anyway, this integration was fairly limited for the real equipments.

Today, if the aforesaid aspects remain important, the training becomes much more collective at the level of crews as well as of small and mid-size formations, typically platoon, squadron or company.

The training insists more than previously on cognitive and decision-making aspects such as the situation awareness from the information collected by the sensors of the vehicle as well as those passed on via data links or audio communications. The co-ordination aspect inside a unit and between units is becoming important.

The tactical environment is more density populated and has acquired intelligence, the natural environment becomes an actor of the scenario influencing the mobility and the capacity of detection of players.

The integration of the simulated vehicle in its operational environment, its connections with the command and control centres are now a must.

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

Finally, it is worth mentioning that many of these new functions can be insured by less expensive equipment, not necessary a faithful replica of a given vehicle. It is the case in France for the systems SYSIMEV and EDITH that THALES recently delivered to the French Army and ALAT (Army aviation).

Operational Analysis

Traditionally the operational analysis is a domain where the industry has had a limited role because of the sensitivity and of the confidentiality of the analyses carried out. However, the industry can supply tools, sometimes stemming from the training simulation, to achieve these analyses.

The evolution mainly concern the ease of operation of those tools, their user friendliness and the soundness of player behaviour. On recent systems the technical and behavioural characteristics of the actors are easily modifiable in an object oriented data base while formerly they were hard coded, 2D and 3D graphic user interface replace boring ASCII files, the interactivity is allowed during and execution, the actors are more numerous, the simulation of their behaviour makes use of the latest advances in modelling techniques such as intelligent agents.

All these advances contribute to a much higher productivity than in the past and thus allows in a given time to explore many more “what if “alternatives.

Support to System Design

It is in this domain that we assist to a real explosion of the use of M&S.

The industry has been using simulation for a long time to support the design of their systems. Simulations used were detailed physical and technical simulations, for example equations of antennae or signal propagation allowing to size the various components of a system and to predict their physical performances. These simulations were used only in design phase and remained with the manufacturer because they contained an important part of company know-how. Today, this kind of simulations remains essential but it is necessary to go further, in particular to identify if the performances and the foreseen features can allow the system to perform correctly its role in a realistic operational environment. For that purpose a global model of the system, driven by the results stemming from detailed engineering models is put in situation in a so-called synthetic environment.

M&S will no longer be restricted to the design phase, but is applicable to the whole life cycle of weapon systems, to the development by virtual prototyping, to the deployment and to the training of operators closing the loop with the first domain of application.

The implementation of simulations in a synthetic environment is carried out by the supplier to demonstrate that its system meets customer’s needs and requirements but also by the customer to compare different alternative solutions. In this phase, it is valuable tool of dialogue supplier/customer.

Finally these technico-operational simulations will be complemented by costing and logistics models allowing to estimate the cost of operation of the system over its life cycle.

These techniques gave birth to processes known under the acronyms SEBA and SBA/SBD for, respectively Synthetic Environment Based Acquisition and Simulation Based Acquisition/Design. While United Kingdom was at the European forefront for their application, in particular within the frame of the evaluation of candidate solutions for the future aircraft carrier, we see now their fast generalisation, France for example, will put them widely into practice to define and assess the architecture of the system of systems known under the name of « bulle opérationnelle aéro-terrestre ».

TECHNICAL EVOLUTION

The major fact of these last ten years is the dramatic decrease of the cost of computer hardware due to the emergence of the PC, this cost not being significant any more in the global cost of a system of simulation. This tendency also extended to 3D graphics boards, pulled by the needs of the video games and which raw performance as well as image quality become sufficient to meet nearly all simulation requirements.

Many simulators or simulations are of the « desk top » type and require little hardware apart from computer. Only the « full mission » simulators (FMS), exact replica of a cockpit, remain expensive because of the use of real aeronautical equipment, instrumentation, on-board computers and of mechanical, hydraulic and optical systems, the cost of which can be hardly reduced.

However, the software whatever the type of simulation remains a time consuming and expensive activity on which we have to focus our efforts.

Several directions are to be considered. At first, the automatic generation of code, either from a high level design language like UML, or thanks to specialised compilers working directly from a computerised « data package » of the reference vehicle, then, by the reuse, the interoperability and the compliance with standards which are closely linked concepts.

The reuse is defined as the capacity to use a simulation outside the context for which it had initially been developed, for example a simulation aimed at virtual prototyping can be then integrated into a training simulator. This reuse is often achieved through interoperability that is the capacity of a simulation to integrate smoothly into a wider environment and to interface with other simulations. This interoperability is made possible by the compliance with some standards of which foremost are HLA, the High Level Architecture developed under sponsorships of the US DMSO and STF, the SEDRIS Transmittal Format for the exchange of data describing the digitized battlefield.

Others, albeit not endorsed by an official standardisation body such as the IEEE and the ISO, have become de facto standards for the industry, among these we can quote the graphic API Open GL and the data format Open Flight.

To make interoperability easier to implement, it is necessary to have « framework » architectures. Frameworks are development as well as execution environments, into which the integration of existing simulations is made easier by automating the generation of the software communication layer. The danger exist, if there is an anarchic proliferation of those frameworks that their development cost exceed the cost of the modelling software that we hook into them and which constitute nevertheless the real added value. Therefore, the domain in which the co-operative research has a sense is that of frameworks, architectures and associated processes.

STATUS OF THE COOPERATIVE RESEARCH IN EUROPE

A good co-operation is established between industries on the large programs of simulation or training. The Eurofighter, the Tiger and probably, in the near future, the NH90, are good examples of such a co-operation. This co-operation is spurred by the governments and is on the model of the one which presided to the development of the real weapon systems.

Unfortunately, we cannot say that the co-operation in technological research is so satisfactory and this for several reasons.

The first one is the insufficient amount of national as well as international funding dedicated to defence research. In most of the European nations the financing of the research for defence is rather low and decreasing, whereas in the US it is high and increasing widening the gap every day. In France, the project of new « Loi de Programmation Militaire » fortunately lets us hope for a progressive improvement of the situation with plans to increase advance research funding by about 20%.

As regards NATO, and in spite of praiseworthy efforts of the M&S co-ordination office which organises this conference, the amounts of funding is disappointing limited. For example, the interesting initiative of distributed mission training known under the name of project SAS-034, is financed by NATO only for the general management part of the program, the rest being funded by the participating nations or even by the industry.

The programs managed by the WEAG under the EUCLID, EUROFINDER and soon EUROPA umbrella, are working slightly better, but there is no more than 10 M€ committed yearly on average by all the 14 nations participating in the CEPA11 which deals with M&S.

The second reason is the administrative complication of the contractual process and the delays which it engenders. It is fair to recognise that there is a significant improvement with the standard contract established by the research cell of the WEAG. However, the differences of procedures and schedule of budgetary commitment in the various nations is still considerably slowing down the EUCLID process. A duration of three years between the first version of an outline description and the awarding of the corresponding contract is not uncommon. The EUROFINDER process is a little faster, of the order of 18 months, but very demanding in terms of industrial self-investment. These durations are not consistent with the speed of evolution of technologies.

Rules « equal participation, equal financing of every nation », and « the financing does not cross the borders » are particularly restricting. For example, the most competent manufacturer in a domain cannot tender in a program if his country cannot engage the necessary financing. In other cases on the contrary it will be difficult, without risks for the program, to assign tasks to a manufacturer with little experience in the domain and participating in a consortium to learn from the others.

As far as PfP nations are concerned they are not at present members of the WEAG and cannot participate in EUCLID and EUROFINDER.

Finally it is fair to say that it can happen that the industry may be reluctant to certain co-operations because the protection of its intellectual property is deemed insufficient. This attitude is however little spread and there are numerous cases where manufacturers authorised that the « foreground » developed in a program be used in a related or continuation programmes even with different participating nations.

THE WISHES OF THE INDUSTRY

First of all it is highly desirable that the importance of the research for defence in particular in the field of M&S, be recognised at national as well as at European level. Duality of the civil and military technologies is often put forward to justify the absence of investments. It is true that this duality exists in certain domains, for example in information technologies and 3D graphics mentioned earlier, however in many domains the defence has its specific technologies. Even when these technologies can have civil applications, as the techniques of CGF applied to the management of civil crisis, they are just emerging and will not pull technology before many years.

If we are not careful our sole choice will be to use technologies of US origin. If Europe has to maintain good technical and scientific relations with our American friends and allies, this does not have to be to the detriment of its own capacity of research and innovation.

We also have to use better our investment and with more reactivity. A way of operating of the WEAG research cell on the model of the European Union framework program, is highly desirable. The WEAG could issue directly invitations to tender opened to all European industries, on the basis of technical specifications developed by the various CEPA. The funding would be insured from a common pot of money fed by the participating nations, the thematic breakdown being made on the basis of a quadrennial budget organised by priorities and being the object of a multinational consensus. These priorities would be refined and declined in concrete projects by every CEPA.

The constitution of the industrial consortia answering the invitation to tender of a CEPA, would be almost free and the participations could be uneven according to the competence of the various participants. Some elementary rules should be set up to protect the spirit of international cooperation. For example, a consortium to be eligible would need participants of two nations at least, no group could have more than 50 % of the funding, the participation of SMEs and of the Academia would be encouraged, etc. An opening to the PfP nations not yet member of the WEAG would be possible under conditions. In this plan, the duration of the contractual cycle, from the issue of the call for tender to the contract award, should be less than one year.

In the field of M&S, the funded common research should aim at developing a set of common, useful technologies in the interest of each of the participating nations. We can quote among others the contribution, with our American partners, to the effort of standardization, the implementation of repositories of models and data and the adoption of common processes for the development of synthetic environments supported by powerful and cost-effective frameworks and toolsets.

In summary, a better awareness in every nation and at the level of the multinational bodies such as NATO and the WEAG of the necessity of investing more that today in modelling and simulation, as well as simplification and shortening of the administrative processes, are the main wishes of the manufacturer.

ABOUT THE AUTHOR

Guy DELEVACQUE is a graduate of the ENST Telecommunications Engineering school in Paris. He joined THALES, at that time THOMSON-CSF, in 1975 as Electronic Warfare programme manager. After responsibilities as export sales manager, he became marketing director and then general manager of Thomson-CSF Communication, Navigation and Identification.

In 1999, he was appointed general manager of Thales Communications Battlespace Radio unit and since 2002 he is Chairman and CEO of Thales Training & Simulation.

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Vues de l'industrie française dans le domaine de la modélisation et de la simulation

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INTRODUCTION

Le domaine de la modélisation et de la simulation ou M&S a connu une profonde évolution ces années, évolution tirée par de nouveaux besoins opérationnels et rendue possible par les progrès rapides de l'industrie informatique.

Les trois champs d'application de la M&S restent les mêmes qu'auparavant, à savoir l'entraînement des combattants, l'analyse opérationnelle et l'aide au développement des systèmes d'armes. Cependant à l'intérieur de chacun de ces domaines applicatifs le recours à la M&S s'est considérablement développé et systématisé conduisant à un changement radical de certains processus, en particulier du processus d'acquisition. L'industrie a dû s'adapter à cette nouvelle donne, voire l'anticiper.

LES DOMAINES D'APPLICATION DE LA M&S

L'entraînement des combattants

L'entraînement d'autrefois, il n'y a pas si longtemps, dix ans au plus, était exclusivement individuel et focalisé sur les aspects connaissance de la plate-forme et de son fonctionnement (la « boutonique ») et psycho-moteurs, c'est-à-dire acquisition des processus réflexes nécessaires au pilotage ou à la conduite de la dite plate-forme. On se trouvait en quelque sorte en la présence d'une super auto-école. Dans ce contexte la représentativité de l'environnement élève était primordiale : fidélité du poste de pilotage ou de conduite ainsi que des restitutions sensorielles, vision, audition et effets kinesthésiques.

L'environnement tactique était rudimentaire, souvent limité à une cible pilotée par l'instructeur et l'environnement naturel quasi inexistant. De plus la plate-forme simulée était peu intégrée dans le système de force auquel elle appartenait, d'ailleurs cette intégration était peu poussée pour les équipements réels.

Aujourd'hui, si les aspects précités restent importants, l'entraînement devient beaucoup plus collectif au niveau des équipages ainsi que des petites et moyennes formations, typiquement un peloton, un escadron ou une compagnie.

L'entraînement insiste plus qu'auparavant sur des aspects cognitifs et de prise de décision comme l'évaluation d'une situation à partir des informations collectées par les senseurs de la plate-forme ainsi que celles transmises par liaisons de données ou communications audio. L'aspect coordination à l'intérieur d'une unité et entre unités devient important.

L'environnement tactique s'est densifié et a pris de l'intelligence, l'environnement naturel devient un acteur du scénario influant sur la mobilité et la capacité de détection.

Communication présentée lors de la Conférence NMSG RTO sur « Les partenariats NATO-PfP/Industrie/Nations dans le domaine de la modélisation », organisée à Paris, en France, les 24 et 25 octobre 2002, et publiée dans RTO-MP-094.

L'intégration de la plate-forme simulée dans son cadre opérationnel, ses liaisons avec les centres de commande et de contrôle sont devenues indispensables.

Enfin, il faut signaler que nombre de ces nouvelles fonctionnalités peuvent être assurées par des équipements moins coûteux car pas forcément fidèles à 100 % à une plate-forme donnée. C'est le cas en France pour les systèmes SYSIMEV et EDITH que Thalès a récemment livrés à l'Armée de Terre et à l'ALAT.

L'analyse opérationnelle

Traditionnellement l'analyse opérationnelle est un domaine où l'industriel intervient peu en raison de la sensibilité et de la confidentialité des analyses menées. Cependant, l'industrie peut fournir des outils, parfois issus de la simulation d'entraînement, pour mener à bien ces analyses.

Les évolutions ont principalement concerné la facilité de mise en œuvre, la convivialité et la fidélité des comportements. Ainsi les caractéristiques techniques et comportementales des acteurs sont aisément modifiables dans une base de données objets alors qu'autrefois elles étaient codées en dur, des outils de dépouillement avec interface graphique 2D et 3D se substituent aux austères fichiers ASCII, l'interactivité est permise durant une exécution, les acteurs sont plus nombreux, la simulation de leur comportement fait appel aux dernières techniques informatiques, en particulier aux agents intelligents.

Toutes ces facilités concourent à une productivité bien supérieure à ce qu'elle était par le passé et permet donc en un laps de temps donné d'envisager beaucoup plus d'alternatives.

L'Aide à la Conception

C'est dans ce domaine que l'on assiste à une véritable explosion de l'utilisation de la M&S.

De tout temps l'industrie a utilisé la simulation pour supporter la conception de ses systèmes. Il s'agissait de simulations physiques et techniques fines, par exemple des équations d'antennes ou de propagation de signaux, permettant de dimensionner les différents composants d'un système et d'en prédire les performances physiques. Ces simulations n'étaient utilisées qu'en phase de conception et restaient chez l'industriel car elles contenaient une part importante de savoir-faire métier.

Aujourd'hui, ce genre de simulations reste indispensable mais on veut aller plus loin, en particulier identifier si les performances et fonctionnalités prévues pourront permettre au système de remplir correctement son rôle dans un environnement opérationnel réaliste. Un modèle global du système, piloté par les résultats issus des modèles fins, est ainsi mis en situation dans un environnement dit synthétique.

La M&S n'est plus limitée à la seule phase conception, mais elle va s'appliquer à l'ensemble du cycle de vie, au développement par le prototype virtuel, au déploiement et à la formation des opérateurs ce qui ferme la boucle avec le premier domaine d'application.

La mise en œuvre de ces simulations dans un environnement synthétique va être le fait de l'industriel pour démontrer que son système remplit bien le besoin mais également par le client pour comparer diverses solutions alternatives. Dans cette phase ce sera un outil précieux de dialogue industriel/client.

Enfin, à ces simulations technico-opérationnelles vont s'ajouter des modèles économiques de coût et de logistique permettant d'évaluer le coût d'exploitation du système sur toute sa durée de vie.

Tout ceci a donné lieu à des processus connus sous les acronymes SEBA et SBA/SBD pour, respectivement Synthetic Environment Based Acquisition et Simulation Based Acquisition/Design.

Le Royaume Uni a été à l'avant-garde européenne pour leur mise en œuvre en particulier dans le cadre de l'évaluation des solutions candidates pour le porte-avions futur mais l'on assiste à leur généralisation rapide, la France par exemple les mettra largement en pratique pour définir et évaluer l'architecture du système de systèmes connu sous le nom de « bulle opérationnelle aéro-terrestre ».

EVOLUTION TECHNIQUE

Le fait majeur de ces dix dernières années est l'effondrement du coût du matériel informatique dû à l'avènement du PC, ce coût n'étant plus significatif dans le coût global d'un système de simulation. Cette tendance s'est également étendue aux cartes graphiques 3D, tirées par les besoins des jeux vidéo dont non seulement la performance brute mais également la qualité d'image deviennent suffisantes pour la plupart des applications de simulation.

Beaucoup de simulateurs ou de simulations sont du type « desk top » et ne requièrent que peu de matériel non informatique. Seuls les simulateurs de type « full mission » (FMS), répliques exactes d'un cockpit restent onéreux en raison de l'utilisation d'équipements aéronautiques réels, instrumentation, calculateurs embarqués et de systèmes mécaniques, hydrauliques et optiques dont le coût est peu compressible.

Le logiciel quant à lui, quel que soit le type de simulation, reste coûteux et c'est sur lui que doivent porter nos efforts.

Plusieurs axes sont à considérer. D'abord la génération automatique de code, soit à partir d'un langage de conception de haut niveau comme UML, soit grâce à des compilateurs spécialisés travaillant directement à partir d'un « data package » informatisé de la plate-forme de référence, ensuite, par la réutilisabilité, l'interopérabilité et le respect des standards qui sont des concepts intimement liés.

La réutilisabilité se définit comme la capacité à employer une simulation hors du contexte pour lequel elle avait été initialement développée, par exemple une simulation à objectif de prototypage virtuel peut ensuite être intégrée dans un simulateur d'entraînement. Cette réutilisabilité passe souvent par l'interopérabilité, c'est-à-dire la capacité d'une simulation à s'intégrer harmonieusement dans un ensemble plus vaste et à s'interfacer à d'autres simulations. Cette interopérabilité est rendue possible par le respect de certains standards dont les plus en vue sont HLA, la High Level Architecture développée sous les auspices du US DMSO et STF, le SEDRIS Transmittal Format pour l'échange des données décrivant un champ de bataille numérisé.

Il en est d'autres qui, sans avoir été soumis à un organisme de standardisation officiel comme l'IEEE et l'ISO, sont devenus des standards de fait pour l'industrie, parmi ceux-ci on peut citer l'API graphique OpenGL et le format de données Open Flight.

Pour que l'interopérabilité soit aisée à mettre en œuvre il est nécessaire de disposer de structures de type « framework », à la fois ateliers de développement et environnements d'exécution, auxquelles on peut intégrer aisément des simulations existantes en automatisant la génération de la couche logicielle de communications. Le danger est grand, s'il y a un foisonnement exagéré, que le coût de développement de ces frameworks ne dépasse le coût des modèles applicatifs qu'on y accroche et qui constituent pourtant la véritable valeur ajoutée. S'il y a donc un domaine dans lequel la recherche coopérative à un sens c'est bien celui des frameworks, des architectures et des processus associés.

L'ETAT DE LA RECHERCHE COOPERATIVE EN EUROPE

Une bonne coopération s'est instaurée entre industriels sur les grands programmes de simulation d'entraînement. On peut citer à titres d'exemples le Eurofighter, le Tigre et probablement dans un proche avenir, le NH90. Cette coopération est voulue par les gouvernements et est calquée sur celle qui a présidé au développement des plates-formes réelles.

En revanche, on ne peut pas dire que la coopération en matière de recherche technologique soit aussi satisfaisante et ce pour plusieurs raisons.

La première est le montant insuffisant des financements nationaux aussi bien qu’internationaux consacrés à la recherche. Dans la plupart des nations le financement de la recherche de défense est faible et décroissant alors que chez nos alliés américains il est élevé et croissant. En France le projet de nouvelle loi de programmation militaire nous laisse heureusement espérer une sortie progressive de la période de vaches maigres mais elle n’est pas encore entrée dans les faits.

En ce qui concerne l’OTAN, et malgré les louables efforts de l’office de coordination M&S qui organise cette conférence, les montants de financement sont peu élevés, par exemple l’intéressante initiative de simulation de mission distribuée connue sous le nom de projet SAS-034 n’est financée par l’OTAN que pour la partie management général du programme, le reste incombant aux nations participantes, voire aux industriels.

Les programmes gérés par le GAEO dans les cadres EUCLID et EUROFINDER et bientôt EUROPA ne sont guère mieux lotis et il n’y a pas plus de 10 M€ engagés annuellement en moyenne par l’ensemble des 14 nations participant au CEPA11 qui traite de M&S.

La seconde raison est la complication administrative du processus contractuel et les retards qu’elle engendre. Il faut reconnaître qu’il y a eu des progrès en la matière avec le modèle de contrat type établi par la cellule recherche du GAEO. Cependant les différences de procédures et de calendrier d’engagement budgétaire dans les différentes nations freinent considérablement le processus EUCLID, une durée de trois ans entre la première version d’une « outline description » et la notification du contrat correspondant n’est pas rare. Le processus EUROFINDER est un peu plus rapide, de l’ordre de 18 mois, mais très exigeant au niveau de l’auto-financement industriel. Ces durées ne sont pas cohérentes de la rapidité d’évolution des technologies.

Les règles « égale participation, égal financement de chaque nation», et « le financement ne traverse pas les frontières » sont particulièrement contraignantes. Par exemple l’industriel le plus compétent dans un domaine ne pourra pas soumissionner dans un programme si son pays ne peut engager le financement nécessaire. Dans d’autres cas au contraire il sera difficile, sans risques pour le programme dans sa globalité, d’allouer des tâches à un industriel peu expérimenté dans le domaine et participant à un consortium pour apprendre des autres.

Enfin, il faut signaler que les nations PfP qui ne sont pas actuellement membre du GAEO ne peuvent participer à EUCLID et EUROFINDER.

Et puisqu’il faut aussi balayer devant notre porte, il peut arriver que l’industriel soit réticent à certaines coopérations car il estime insuffisante la protection de sa propriété intellectuelle. Cette attitude est toutefois peu répandue et il y a de nombreux cas où des industriels ont autorisé que le « foreground » développé dans un programme soit utilisé dans un programme suite ou connexe.

LES SOUHAITS DE L’INDUSTRIEL

Tout d’abord il est éminemment souhaitable que l’importance de la recherche de défense, en particulier dans le domaine de la M&S, soit reconnue à l’échelon national comme à l’échelon européen. On entend souvent évoquer la dualité des technologies civiles et militaires pour justifier l’absence d’investissements. Il est vrai que cette dualité existe dans certains domaines, par exemple l’informatique et le graphique évoqués plus haut, cependant dans bien des domaines la défense a ses technologies propres. Même lorsque ces technologies peuvent avoir des applications civiles, comme les techniques de CGF appliquées à la gestion de crise civile, celles-ci émergent à peine et ne sauraient tirer la technologie vers le haut avant de nombreuses années.

Si nous n'y prenons pas garde nous nous condamnons à terme à n'utiliser que des produits techniques d'origine américaine. Si l'Europe doit garder de bonnes relations techniques et scientifiques avec ses amis et alliés américains ce ne doit pas être au détriment de sa propre capacité de recherche et d'innovation.

Nous devons également mieux utiliser notre investissement et avec plus de réactivité. Un fonctionnement de la cellule recherche du GAEO sur le modèle du PCRD de l'Union Européenne est éminemment souhaitable. C'est-à-dire que le GAEO pourrait émettre directement des appels d'offres ouverts à l'ensemble des industriels européens, sur la base de spécifications techniques émises par les différents CEPA. Le financement serait assuré par un pot commun alimenté par les nations participantes, la ventilation thématique se faisant sur la base d'un budget quadriennal organisé par priorités faisant l'objet d'un consensus multinational. Ces priorités seraient affinées et déclinées en projets concrets par chaque CEPA.

La formation des consortia industriels répondant à l'appel d'offre d'un CEPA serait quasi libre et les participations pourraient être inégales en fonction des compétences des différents participants. Seuls des garde-fous élémentaires seraient mis en place pour préserver l'esprit de coopération internationale. Par exemple pour qu'un consortium soit éligible il faudrait des industriels de deux nations au moins, aucun groupe ne pourrait disposer de plus de 50% du financement, la participation des PME et de l'Université serait encouragée, etc. Une ouverture aux nations PfP non encore membres du GAEO serait possible sous conditions. Dans ce schéma, la durée du cycle contractuel, de l'émission de l'appel d'offres à la notification devrait être inférieure à un an.

Dans le domaine de la M&S la recherche financée de façon commune devrait viser à développer un ensemble de technologies communes, utilisables dans chacune des nations participantes. On peut citer entre autres la contribution, avec nos partenaires américains, à l'effort de standardisation, la mise en place de banques de modèles et de données (repositories) et l'adoption de processus communs de développement d'environnements synthétiques supportés par un outillage, des « frameworks » eux aussi communs.

En résumé une meilleure prise de conscience dans chaque nation et au niveau des organismes multinationaux comme l'OTAN et le GAEO de la nécessité d'investir plus qu'aujourd'hui dans la modélisation et la simulation, sources d'économies futures ainsi qu'une simplification et un raccourcissement des processus administratifs, sont les souhaits principaux de l'industriel.

A PROPOS DE L'AUTEUR

Guy Delevacque, diplômé de l'ENST Paris, est entré à Thalès, à l'époque THOMSON-CSF en 1975. Après un poste de responsable de programmes de guerre électronique, il devient responsable commercial Asie, puis chef de service commercial Europe. En 1990, il est nommé directeur commercial de la division Communication, Navigation, Identification, dont il devient directeur général en 1996. En 1999, il prend la direction de l'activité « Battlespace radio unit » de Thalès Communication. Depuis février 2002, il est Président Directeur Général de Thalès Training & Simulation.

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Regional Security Cooperation through Education and Training Technology

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Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

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Working with Industry – The UK MoD Experience

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Partnerships that Work – A Review of US Government/Industry Cooperative Research Agreements

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1.0 INTRODUCTION

1.1 Rationale

The purpose of this paper is to familiarize the reader with the methods that industry and US Government agencies use to share research and technology. During the course of the discussion, the reader will become familiar with the basis in law that supports these regulations, the primary vehicles used to formalize cooperation, and see examples of relevant programs. This presentation also lists various Internet sites that contain additional information.

1.2 Legal Background

The Stevenson-Wydler Act (15 USC 3701 et seq.) made technology transfer a part of the mission of every federal laboratory. Its intent was to maximize the benefit of taxpayer investment in federal R&D. The Federal Technology Transfer Act of 1986 (PL 99-502), which amended the original law, provided significant new authorities for Army laboratories to establish Cooperative Research And Development Agreements (CRADA) with private companies, as well as with public and non-profit organizations. Further, PL 99-502 authorized and Executive Order 12591 required that the commander or director of each appropriate Army R&D activity be delegated the authority to enter into CRADAs and to license, assign, or waive rights to intellectual property on behalf of the government. The National Technology Transfer and Advancement Act of 1995 (PL 104-113) amended these previous laws to provide additional incentives that encourage technology commercialization for both industry partners and federal inventors. It sought to promote industry's prompt deployment of inventions developed under a CRADA by guaranteeing the industry partner sufficient intellectual property rights to the invention, and providing increased incentives and rewards to laboratory personnel who create the inventions.

1.3 Overview

A long history of technology transfer exists between Army labs and R&D centers and the commercial and non-federal sector. Army technology can help to produce a stronger civilian economy, but only in partnership with academia and U.S. industry, who can advance new technology and bring new products, processes and services to the marketplace. Army technology transfer programs are a partnership with industry and academia to foster rapid, diverse, and profitable spin-offs of Army technologies to the non-federal sector and to promote dual-use technologies that simultaneously support both military and economic needs.

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2.0 COOPERATION AGREEMENTS

2.1 What is a MTA?

A Material Transfer Agreement (MTA) is a negotiated contract between the owner of a tangible material and a party seeking the material and the right to use the material for research purposes. The material may be either patented or not. Material transfer agreements tend to be shorter than license agreements, and they are generally considered more informal than license agreements, although both are enforceable contracts. The purpose of an MTA is to document the transfer and outline the terms of use, including identification of the research project, terms of confidentiality, publication, and liability. As with licenses, there are no standard MTAs. MTAs do not usually require financial payments at the time of the transfer, but many MTAs allow the provider to either own, or license exclusively, or obtain payments upon the sale of developments that the recipient makes with the provider's materials. These are loosely called "reach-through" provisions, and are considered by many providers to be desirable because they allow the provider to obtain rights in subject matter that the provider would not otherwise have rights to through its ownership or patent coverage of the material alone. Reach-through provisions are considered undesirable by many recipients because they burden all the developments created after the use of the material, and because they are seen as providing an unfairly high level of compensation to the provider for use of the material. It is more common to find MTAs used in applied research projects than in most other areas of research and development.

2.2 What is a CRADA?

A CRADA is a Cooperative Research and Development Agreement. It is a written agreement between a private company and a government agency to work together on a project. By entering into a CRADA, the Federal government and non-Federal partners can optimize their resources and economically perform research by sharing the costs of this research. The collaborating partner agrees to provide funds, personnel, services, facilities, equipment or other resources needed to conduct a specific research or development effort while the Federal government agrees to provide similar resources *but not funds* directly to the partner.

The CRADA vehicle provides incentives that can help speed the commercialization of federally developed technology, making it an excellent technology transfer tool. The Government protects any proprietary information brought to the CRADA effort by the partner. This provides a true collaborative opportunity. Federal scientists can work closely with their non-Federal counterparts, exchanging ideas and information while protecting company secrets. Also, all parties can mutually agree, if they so desire, to keep research results emerging from the CRADA confidential and free from disclosure through the Freedom of Information Act for up to 5 years. CRADAs also allow flexibility in patenting and patent licensing; enabling the government and the collaborating partner to share patents and patent licenses or permitting one partner may retain exclusive rights to a patent or patent license.

2.3 To Summarize, CRADAs offer the Following Benefits:

- Enable both partners to stretch their research budgets and optimize resources.
- Provide a means for sharing technical expertise, ideas, and information in a protected environment. The Federal government can protect from disclosure any proprietary information brought to the CRADA effort by the partner(s).
- Permit Federal and non-Federal scientists to work closely and offer non-Federal partners access to a wide range of expertise in many disciplines within the Federal government.
- Allow the partners to agree to share intellectual property emerging from the effort or to agree that one partner may retain exclusive license to patent research.

- Permit the Federal government to protect information emerging from the CRADA from disclosure for up to 5 years, if this is desirable.
- Most CRADAs are 100% industry-funded, although costs may be shared through contributions of personnel, equipment, services, or facilities.

2.4 When do I use an MTA or a CRADA?

An MTA generally is used when any proprietary material and/or information is exchanged, when the receiving party intends to use it for his/her own research purposes, and when no research collaboration between scientists is planned. Neither rights in intellectual property nor rights for commercial purposes may be granted under this type of agreement. MTAs define the terms and conditions under which the recipients of materials, provided by either the researcher or the other party, may use the materials. Included in the MTA are the requirements to use the materials for research purposes only.

CRADAs are used when a cooperative R&D project between the US Government and the private sector is contemplated. CRADAS allow for the exchange of material and/or research and development collaboration over a substantial period. CRADAs are also used when one or more parties supply staff or equipment; or when the industrial partner contributes funding or requests the granting of intellectual property rights. A CRADA may also be necessary in instances where a company is providing an otherwise non-available material and requests the transfer of intellectual property rights in the result of associated research.

3.0 SUCCESS STORIES

The following projects demonstrate for the reader some specific examples of how technology transfer has benefited both industry and the US Government.

3.1 A Billion-Dollar Library of Training Tools

The Army's Simulation, Training, and Instrumentation Command (STRICOM) helped form the Training and Simulation Technology Consortium (TSTC) of Orlando, FL. This project stemmed from the need to bridge the gap between those needing training expertise and the $1 billion-plus inventory of training solutions. The TSTC is a group of three DOD/NASA agencies, four defense contractors, and an educational institution. Each of these organizations is a recognized leader in the field of training and simulation technology.

The Army, along with the other TSTC founders, built an inventory of advanced training solutions valued at more than a billion dollars. These high-technology simulation and training solutions are in use around the world under the most challenging circumstances. TSTC provides an opportunity for private sector organizations to gain from government-funded training research and development. The Consortium, which received $2.4 million initial funding in May 1994 through the ARPA Technology Reinvestment Program, matched the grant and that resulted in a three year $4.8 million program. TSTC provides technology and expertise of its members to proposed target audiences. The following lists a few of the available capabilities in general terms.

3.2 Simulation

Using computers, video screens, and control panels to reproduce in sight and sound what likely will occur in actual performance, simulation is a training tool the Army and other Consortium members use to reduce the cost and danger of training personnel to operate sophisticated equipment in a realistic arena (actual conditions). Military and space projects have proven the merits of simulation as a training tool. Many accidents are avoided when an inexperienced operator is allowed to practice on a simulator before moving to the actual equipment.

For even the most experienced operators, simulation provides an opportunity to practice emergency maneuvers and other procedures that are too dangerous to perform in the field, or simply to hone their skills at little cost to the taxpayer.

Simulators have virtually no impact on the environment, and reduce the amount of fuel, ammunition, equipment wear and tear, and other resources consumed in field training. Many simulation systems in the Consortium’s library have direct relevance to industrial and government needs, such as firearm and tactical training for law enforcement officers, driver training for commercial truck and bus operators, and flight training for commercial pilots.

3.3 Distributed Interactive Simulation

The DOD has expanded the use of simulation technology by tying together related simulation activities, allowing users to interact in a multidimensional setting. For example, Distributed Interactive Simulation can be used to allow a tank commander at Fort Knox in Kentucky to participate in a simulated field exercise with an F-14 pilot at the Naval Air Station in Pensacola, FL. Both participants can communicate and interact as if they were operating their respective equipment in the same area. This parallels industrial and government applications such as disaster planning, emergency response, and hostage situations, where multiple organizations at multiple locations must train together to function as an effective team.

3.4 Virtual Reality

Like simulation, virtual reality technology allows an operator to experience phenomena likely to occur in actual performance, bringing with it all the advantages of simulation. Unlike conventional simulation with mock-up control panels and two-dimensional images projected onto a screen or video monitor, virtual reality projects the operator into a three-dimensional simulation. Images are projected onto special goggles to create a three-dimensional effect. Other equipment is used to sense head, body, leg, arm, and hand motion, allowing the operator to move in virtual space and even touch virtual objects.

3.5 Computer-Based Training

The military pioneered the instructional design process and has set the standard for design and development of computer-based training, including the integration of computers, CD-ROM, audio, touch-screens, video, and the like. The military's Defense Instructional Technology Information System (DITIS) lists over 3,000 interactive training courses already prepared.

Consortium members have developed several instructional design and development tools to help produce custom courseware for many of the tasks associated with training in today's fast-paced market. These off-the-shelf tools and relevant courses can increase the efficiency and return on investment of custom course development.

3.6 Electronic Performance Support

Whether on the battlefield or in a high-technology factory, the ability to quickly retrieve and understand information is critical to an operation's success. An Electronic Performance Support System (EPSS) uses interactive multimedia systems to provide technical workers with information, computer-based training, reference databases, and on-line help/advice. Using a multimedia approach, the system can communicate information through text, pictures, sounds, and video clips, directly to the shop floor. Through the use of EPSS, the military has experienced substantial decreases in training time, cost, and paper documentation while increasing employee retention and productivity.

3.7 Decision Support

Consortium members have developed tools to help managers plan for and execute change within their companies. Time-proven analysis techniques have been developed for estimating personnel and training requirements for new or modified operational systems or production facilities. These decision-support tools provide methods to estimate life cycle costs, labor requirements, inventory levels, and schedule implementation rates. They also can be used to identify required personnel aptitudes and characteristics for the new systems or procedures. These tools are invaluable for rapid and successful expansion planning, new technology implementation, and manufacturing process development.

3.8 Improving Helicopters

Helicopters are playing a more important role in solving commuter transportation problems. Already, over 6,000 civilian helicopters operate in the United States-and this number is growing quickly. The Army, with its vast experience in helicopter design and operation, is helping commercial firms create the next generation of helicopters that can fly more safely, faster, and on less fuel. Following are two examples of how the Army is helping commercial firms design better helicopters.

3.9 New Analysis Tool

The Aeroflightdynamics Directorate of the Army Aviation and Troop Command (ATCOM) has developed and transferred a new comprehensive computer software system to the U.S. helicopter industry to help design both military and civilian rotorcraft. The sophisticated program's rotorcraft analysis capabilities go far beyond those available with previous systems, including rotor configuration (articulated, tandem, tilt rotor, etc.), fuselage shape, auxiliary lifting surfaces, automatic flight control, propulsion and drive systems, and aerodynamic effects. Designed for ease of use, the program has a fully interactive, menu-driven user interface.

A multidisciplinary and multi-organizational approach resulted in a superior analysis tool for all stages of rotorcraft development from basic R&D to design, testing, and performance evaluation of the finished product. Development team members include helicopter manufacturers Sikorsky Aircraft Co., McDonnell Douglas Helicopter Corp., Boeing Helicopter Co., and Kaman Aerospace Corporation; R&D firms United Technologies Research Center, Computer Sciences Corp., Sterling Federal Systems, and Advanced Rotorcraft Technology, Inc.; and universities University of Maryland, Georgia Tech Research Institute, and Rensselaer Polytechnic Institute.

The Army released the first version (V 2.3) for commercial use in March 1994. The software has been distributed to over 15 industry, government, and university sites in the United States. The Aeroflightdynamics Directorate has held training classes to provide a hands-on transfer of this Army technology to both government and private sector users. In addition, the Directorate provides continuing user support to maintain, enhance, and validate the program.

3.10 Rotor Blade Load Prediction

The Army Research Laboratory (ARL) Vehicle Structures Directorate entered into two Cooperative Research and Development Agreements (CRADA) to enhance a software tool for predicting the loads or forces on a helicopter rotor blade during flight. Although this analysis is limited to just one part of the helicopter (the rotor blade), it represents a tremendously complex engineering problem. Unlike fixed-wing aircraft, helicopters receive lift, direction, and speed from long, slender blades that flex, bend, twist, and vibrate while rotating at high speeds. The Army is helping commercial firms improve their ability to predict rotor blade behavior.

The goal of one CRDA, with Advanced Technologies, Inc. (ATI), is to enhance the University of Maryland's Advanced Rotor Code (UMARC). The data from this engineering software package provides a detailed, visually represented span wise load distribution. This CRADA brings together two former colleagues with key experience: Dr. Mark Nixon of ARL and Dr. Naipei Bi of ATI. Both were instrumental in the original development of the UMARC program while working on their Ph.D.s at the University of Maryland. Thanks to the CRADA technology-transfer mechanism, they could collaborate once again to improve the UMARC program.

Using pictures of predicted loads on a rotor blade that show how the loads vary along the length of the blade, engineers design blades that will safely lift more with less fuel use. ATI is now using this Army technology to improve the design of the commercial S-61 helicopter. In addition to helping ATI solve this problem, the UMARC enhancement will also give the Army more data to better understand the forces exerted on rotor blades used in military aircraft.

The other CRDA, with Sikorsky Aircraft, enhanced the Sikorsky version of the UMARC code to include a bearingless-gimbal rotor configuration and new trim options for tilt rotors. These features allow Sikorsky to perform analysis in support of its Variable Diameter Tilt rotor (VDTR) concept, and will bring new, improved analysis tools to the Army as well.

Sharing Army technology with commercial firms may make rotorcraft commuting a viable option for the civilian worker of the future.

3.11 Reconfigurable Asymmetrical ISR Development (Raid)

Intelligence, Surveillance, and Reconnaissance (ISR).

The RAID simulation simulates the sensor system, target object models, and the intelligence cycle. The purpose of RAID is to provide users with a tool that will provide credible data for use in Advanced Concepts Research (ACR). This is a cooperative program between the Battle Command Battle Lab (BCBL) at the US Army Intelligence Center, Ft. Huachuca, AZ and an industry leader in simulation design, Veridian Information Solutions (VIS). In this cooperative effort, the BCBL provides facilities, projects, and subject matter expertise that will improve Raid's functionality. VIS provides all software engineering, project management, and allows BCBL unrestricted local use of the RAID software.

The RAID sensor system models are wholly re-used software objects originally developed for the Joint Tactical Intelligence Model (JTIM), formerly known as the WARSIM Intelligence Module (WIM) federate of the Joint Simulation System (JSIMS). The RAID combat models provide HLA Federate Objects (FO) and Interaction data consistent with the JSIMS Federate Object Model (FOM).

RAID builds on JSIMS Common Components (SNE, CCSE, HLA-RTI, SCC, et al.) and intelligence models initially developed for JSIMS training application JTIM. RAID will provide the user an ability to configure the simulated battlespace with sensor systems and target models of both OPFOR and BLUFOR. The modeling technique allows sensor and target models to be re-parameterized to support new or proposed systems and architectures.

RAID is a comprehensive simulation that meets Service and Joint ACR modeling requirements, spanning tactical to strategic-national echelons. RAID creates a simulation environment that stress intelligence assets and provide data that quantifies the effectiveness of intelligence systems and architectures. RAID will evolve fully to support the conclusion phase of the ACR process.

RAID sensor system models simulate the six phases of the intelligence cycle (Planning and Direction; Collection; Processing and Exploitation; Production: Dissemination and Integration; Evaluation) for purposes of assessing multi-service intelligence architectures. RAID re-uses JTIM and select JSIMS common components to simulate intelligence assets and behaviors, interface to Command, Control, Communications, Computers and Intelligence (C4I) systems, support intelligence analysts through user interfaces, and After Action Review (AAR) analysis.

RAID sensor system models represent Signals Intelligence (SIGINT), Imagery Intelligence (IMINT), Measurement and Signature Intelligence (MASINT), and Human Intelligence (HUMINT) collection systems, that includes tasking and the products these intelligence disciplines produce. Intelligence products from RAID sensors will exist at varying levels of detail (raw data, initial interpretation, correlated, and fused) depending on the analysis objectives and focus of the user-designed architecture.

Practical use of RAID will assist developers in providing definitive data to support:

- The design of future intelligence architectures
- The value of various collection assets
- Evaluate various intelligence processes
- Optimize intelligence collection for contingency operations
- Optimize intelligence collection for current operations
- Assist Commanders and Staffs in designing force protection packages
- Enterprise level simulation exercises

4.0 CONCLUSION

This paper has provided the reader with a broad explanation of how the US Government and Industry shares resources to the benefit of the collaborators and other interested parties. The support of this goal came from providing the basis in law the supports cooperative research, the various methods of regulation of cooperation, and examples of cooperative programs. The author's intent is to provide a working model that other nations may wish to use as a basis of cooperative research to meet their own requirements.

5.0 ADDITIONAL RESOURCES:

The following Internet web sites provide additional information of the various programs highlighted in the paper. The web sites also include generic agreement forms for review. The reader should note that there are no standard requirements for these agreements.

http://www.arl.army.mil

http://www.crrel.usace.army.mil/partnering/partnering.html

http://ott.od.nih.gov

http://www.usgs.gov/tech-transfer/what-crada.html

http://www.dtic.mil/techtransit/

The Cost Effective Development of HLA Federations for Computer-Assisted Exercises (CAX)

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ABSTRACT

The use of Computer Assisted eXercises (CAX) for the training of NATO staff personnel has been exploited successfully for quite a long time. To satisfy the statements of the NATO Modelling and Simulation Masterplan, and thereby to intensify the cost saving effect for simulation systems (a CAX is a kind of a simulation system), NATO decided to conduct the PATHFINDER experiment as the successor of the DiMuNDS 2000 project. One important issue is to establish a generic interconnection to a Command Information System (CIS) that may be re-used in future applications.

This paper suggests – based on a number of lessons noted, limitations, and deficiencies from DiMuNDS 2000 – a bunch of measures, which should be addressed within PATHFINDER (and beyond) and any federated simulation supported CAX. These issues may be divided into the following areas: Technical Management, Administrative Management, Modelling, and Technical Infrastructure.

INTRODUCTION

In 1998 the idea was conceived to conduct a multi-national distributed simulation to prove the concept of the High Level Architecture (HLA) and to demonstrate the cost-effective employment of national models and simulations to support National and NATO Computer Assisted Exercising (CAX). The demonstration of the feasibility and operational viability of this concept was scheduled in two phases: the Distributed Multi-National Defence Simulations programme (DiMuNDS 2000) and a follow-on PATHFINDER programme[1].

The DiMuNDS project was a highly successful precursor experimental system which established the technical viability of combining multi-national simulations using the HLA for the purpose of providing training/ exercises in a Combined-Joint Task Force (CJTF) operational context. This programme demonstrated its military capabilities in the NATO M&S Conference in October 2000. The Pathfinder Programme aims to implement a technological leap-ahead in capability benefits for NATO and PfP. Initially, this capability development will focus on the training of the NATO Combined Joint Tactical Force (CJTF) and component commanders, but the PATHFINDER product has application to a much wider audience.

[1] Note: although the term “distributed simulation” is very commonly used, within this paper “federated simulation” is preferably used to stress the point that the emphasis of PATHFINDER and similar experiments is on coupling simulations that origin from independent sources.

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Essentially, PATHFINDER seeks to develop an integration environment in which national simulation models and decision support tools can be federated to provide a bespoke capability to match the demands of individual Users and the evolving complexity of modern warfare. Where possible, the component simulations will cover the full spectrum of warfighting and offer various degrees of fidelity.

THE NATO M&S MASTER/ACTION PLAN

The overall mandate to conduct DiMuNDS 2000 and PATHFINDER results from the NATO Modelling & Simulation Master Plan (NMSMP) [1] and the derived Action Plan.

The Action Plans identifies 5 main objectives for M&S:

1) to establish a Common Technical Framework to foster interoperability and reuse;
2) to provide Common Services to increase Cost Effectiveness in NATO M&S activities (including the provision of M&S education to NATO Nations and PfP; the promotion of sharing of M&S resources through a simulation resource library (SRL));
3) to develop Simulations;
4) to employ Simulations to enhance NATO mission effectiveness;
5) to incorporate technological advances: M&S-related technology advances are expected to occur frequently and will provide opportunities to increase functional capabilities, performance and overall M&S effectiveness. To assist M&S users in maintaining awareness of such M&S-related technology developments, NATO should monitor technology developments by others and to conduct its own technology-development activities in key areas not addressed elsewhere.

The recommendations given further below fit very well to the above mentioned objectives.

EXERCISING IN THE REAL ENVIRONMENT

From the operational point of view, conducting a CAX in a real environment is vital for achieving the training purpose and consequently for user acceptance. A real environment in this context simply means interacting with the CIS as it is used during mission. In other words, the simulation systems assisting the exercise should be invisible to the training audience.

This can generally be achieved in three different ways:

1) via a swivel chair: the information from/to the CIS is inserted in the configuration files of the simulations (the “old fashioned method”);
2) via a proprietary or NATO protocol, i.e. ADat-P3: many CIS rely on ADat-P3 messages for information exchange. Since these are regularly ASCII-files, it is easy to parse the message electronically; this is simply the automation of variant 1 (the “usual way”);
3) via a replication mechanisms: this maps the data structure of the CIS to the data model of the federation, enabling an automatic data exchange (the “onthologic way”).

In more detail, the replication is much more than a simple replication of data bases: it includes the mapping of two different data structures in terms of semantics and logics. Unfortunately, the *representation* of the (perceived) truth in a CIS on the one hand and a simulation system on the other is usually very different, thus leading to severe problems in interoperability.

Very recently, a comparison of the U.S. Army Object Model Standards Category (OMSC) for M&S and the Army Integrated Core Data Model (AICDM) for CIS was published [7], concluding that interoperability between these can hardly be achieved unless some modifications are applied.

Thus, for experiments like PATHFINDER it can be concluded that:

- either the coupling is established via proprietary protocols,
- or efforts need to be launched, to establish a generic mapping mechanism.

From a pragmatic point of view it is recommended to undertake both: using the proprietary protocol as used by the CIS in order to meet the timeline of PATHFINDER, but additionally fostering efforts towards a sophisticated technical infrastructure.

THE REQUIREMENT FOR A TECHNICAL INFRASTRUCTURE

The requirement for interconnecting CIS and simulation systems is motivated not only from the perspective of cost-effectiveness for CAXs, but also from the operational view for purposes of decision support and/or operational planning [3-5].

As widely known, CIS and simulation systems exploit various communication mechanisms. Hence, it is desirable to keep the systems separated with respect to their peculiar communication mechanism and to loosen the coupling as far as possible.

From a more abstract point of view upon federated systems – regardless whether we are dealing with linked CIS or linked simulation system – one encounters a striking similarity: as in the case of the Multi-national Interoperability Programme (MIP), where several national CIS based on the ATCCIS model are linked, the distribution within a HLA federation relies on devoting to a common FOM. If we take another step on the ladder of abstraction, then one can introduce a so-called *Data Mediation Functionality* (DMF): exploiting techniques already used for e.g. NC3DM or SEDRIS (therefore denoted as a reference or common data model) allow generally for converting one data base format into another.

However, this approach is based on the assumption that the data models and/or data structures of the underlying data structure reflect states of military relevance. Only then a transformation from CIS to the simulation system and vice versa via a reference data model can succeed: $\psi_{MIP} = \mathbf{O}\ \psi_{Sim}$ and $\psi_{Sim} = \mathbf{O}^{-1}\ \psi_{MIP}$, with **O** as the operator for the CIS-Sim-Coupling.

It is most important to note that the linkage of CIS and simulation systems is still an issue of R&D efforts and that we are far from having a solution [6]. Up to now, mainly two approaches were taken: the one – motivated by the simulation systems' community – tried to urge the CIS to commit to a FOM. The other – motivated by the CIS community – tried to force a simulation to interact via the CIS peculiar message protocols. Although both approaches have their pros and cons and have demonstrated to be feasible, they are not very universal. With PATHFINDER – still in the domain of a R&D project – it is therefore recommended to investigate the use of a CIS-Sim-Coupling device (the **O**) to establish the coupling.

Generally speaking, coupling a simulation systems and a CIS is not a trivial issue. Assuming that the simulation system is HLA compliant, it is represented by its Simulation Object Model (SOM). The CIS, on the other hand, is to be expressed in terms of its internal data base structure: this may be ATCCIS[2], or more likely any data model. Hence, any generic mapping mechanism must enable mapping of arbitrary data models to FOMs. Clearly, it is necessary to know the data models behind the CIS to be coupled as

[2] Army Tactical Command and Control Information System.

early as possible in order to “align”[3] them. Furthermore, the Run-Time Infrastructure (RTI) is usually not an appropriate software layer interconnecting CIS systems or modules of them.

Concerning the coupling of simulation systems, it is often not realised that interoperability demands for more than mere “*HLA compliance*”: interoperability demands for data standards as well as for a common understanding of modelling. Otherwise the HLA is reduced to the RTI and is then yet another communication medium.

So far, there are some efforts evolving that addresses the issue of CIS to Simulation coupling [2, 4, 5, 7]; they are mainly governed by U.S. initiative, but also some European countries have recently developed some promising ideas.

LESSONS NOTED FROM DIMUNDS 2000

When progressing from DiMuNDS 2000 to PATHFINDER, the scope is not on one single focus, but takes several tasks and restrictions into account:

- the availability of simulation systems provided as national voluntary contributions;
- the support of a particular scenario without limiting the scope of future scenarios;

but still:

- establishing a technical infrastructure and
- proving the PATHFINDER concept as outlined earlier.

These first two circumstances usually endanger to end-up in solutions that are suited only for one specific CAX under consideration and that are hardly re-usable[4], hence preventing the proof of concept. Therefore, is becomes important to draw attention to some aspects which are regularly neglected:

- Data Exchange Formats;
- the discussion of Federated vs. Monolithic Simulation,
- and the aspects of Modelling and Simulation.

Of course, each federation has at some time to address topics like the big/little endian[5] problem[6]. Within DiMuNDS 2000 this was solved very effectively by using the XDR standard.

When addressing the topic of data exchange formats the focus is not on distributing the SOM/FOM information in terms of their DIF, i.e. the omd-file in BNF, but on the data to be federated via the RTI. The RTI does not provide a coding scheme for the representation of the byte stream, hence the applications have – as a part of the FEDEP – to agree on the data representation and if a mismatch is encountered they have to write the re-coding code. Within DiMuNDS 2000 the problem was very elegantly solved by adopting the XDR standard.

XDR is a standard for the description and encoding of data. It is useful for transferring data between different computer architectures. It fits into the ISO presentation layer, and uses a language to describe

[3] In using the expression “align” the author follows [7].

[4] Often referred to as proprietary solution.

[5] The way data is coded into a bit stream.

[6] At least is the simulation systems are running on different platforms.

data formats[7]. Protocols such as Sun RPC (Remote Procedure Call) and the NFS (Network File System) use XDR to describe the format of their data. Although XDR is still widely used, more modern concepts for federated applications include this problem already: within the CORBA standard, data representation is already standardised and referred to as CDR (Common Data Representation). CDR plays a similar role as XDR, however it is already part of commercially available ORBs.

Summarising:

when setting-up the PATHFINDER federation, the potential participants should recognise that within the DiMuNDS 2000 project a library for data conversion in accordance with the XDR standard was established. Furthermore, if in future extensions of the PATHFINDER project a technical infrastructure after the pattern of the French ESCADRE or the German PSI-SA/GERTICO should come into service, this should be based on a standard in accordance with standards defined by Object Management Group (OMG)[8] [8], and hence addresses the data exchange problem.

CONSEQUENCES FROM DIMUNDS 2000 TO THE MSG TASK GROUPS

The following areas appear vital to the successful establishment of federated simulations interconnected to CIS and capable to support CAX.

Technical Management;

- Deriving Data Models;

Administrative Management;

- Deriving Authoritative Data Sources;
- Defining clearly a scenario;

Modelling;

- Modelling Technique;
- Use of Modelling Tool-Kits;

Technical Infrastructure.

- Generating rapidly a Scenario;
- Coupling simulation system with CIS;
- Data Marshalling.

Although, different bodies[9] have already addressed some of those problems/limitations, a short-term guidance document for federated simulation supported CAX experiments has not been produced. The establishment of a CAX using federated simulation (unlike a “conventional” CAX) imposes the above mentioned problems to obtain the benefit of flexibility and re-use of systems.

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[7] Note that the XDR is a description, not a programming language.

[8] The OMG is a non-profit organisation with more than 1000 members from industry and academia to define standards for the interoperability of distributed object-oriented software applications.

[9] Defense Modeling and Simulation Office (DMSO), Simulation Interoperability and Standardization Organization (SISO), NATO Modelling and Simulation Group (NMSG), and national authorities (e.g. Daten Management Organisation der Bundeswehr (DMOBw) in Germany).

Presently, NSMG is dedicated to M&S by 14 approved Task Groups. Unfortunately, only 2 of them are explicitly dedicated to the PATHFINDER project: MSG-002 and MSG-005 plus the PATHFINDER Steering Group.

In order to foster PATHFINDER and to avoid some experiences as encountered during DiMuNDS 2000, it appears reasonable, to focus some of the NMSG TAPs in more strength to PATHFINDER. Figure 1 summarises the relationship between different NMSG TAPs and some suggestions given within this paper. Although, many of the NMSG TAPs are devoted to identified problems, only few[10] of the recommended tasks are covered. Some of the important ones are up to now not addressed at all.

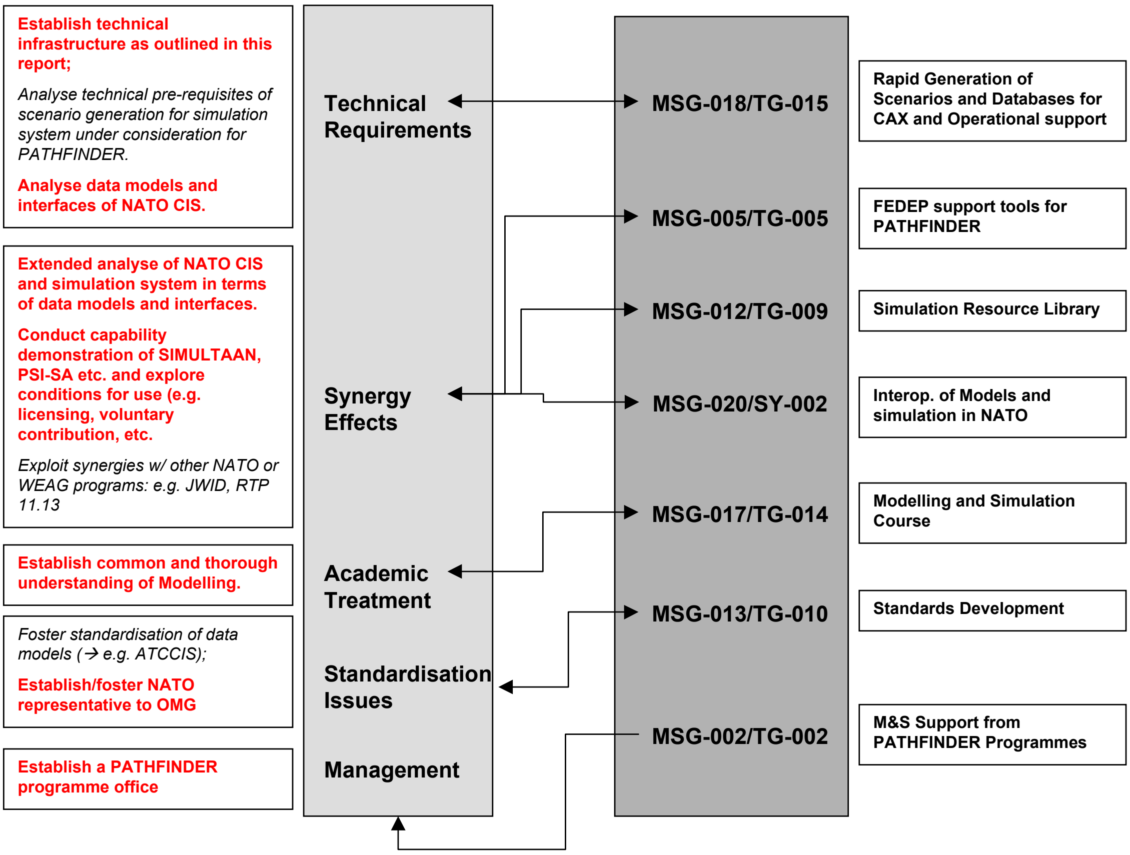

Figure 1: Relationship of NMSG TAPs and Recommendation of this Report.

Consequently, meeting the above mentioned demands should by performed to the highest possible extend through the existing NMSG TAPs. However, this appears not appropriate, where PATHFINDER and/or similar programmes requires crucially for a technical outcome. For this case, there is the need of a dedicated "Programme Office", manned by national (as in the case of DiMuNDS 2000) and some NATO technical experts. It is important to note that this "Programme Office" should be responsible for technical decisions and its tasks are:

- to establish a technical infrastructure;
- to run through all the PADEP steps as necessary;
- and, finally, to conduct the concrete experiment, e.g. PATHFINDER.

[10] Printed in italics in Figure 1.

The remainder of the NMGs – if launched at all - is recommended to be re-focused as follows[11]:

- MSG-018/TG-015: analyse the technical pre-requisites of scenario generation in general, and *demonstrate the feasibility of the results with the ARRCADE FUSION 03 scenario*.
- MSG-012/TG-009: Outline a Simulation Resource Library and *include an analysis of NATO CIS interfaces and review capabilities of simulations frameworks (like SIMULATAAN (NL), PSI-SA (GE), ESCADRE (FR) as available for NATO)*.
- MSG-020/TG-014: *Conduct extended analysis of NATO CIS' and simulation systems' data models and interfaces*[12].
- MSG-017/TG-014: *Establish common and thorough understanding of Modelling*[13] *including review of current commercial developments like the MDA [8]*.
- MSG-013/TG-010: *Establish a NATO representative to OMG.*
- MSG-002/TG-002: Establish a PATHFINDER "Programme Office".

CONCLUSIONS

It is important to note that PATHFINDER and subsequent simulation based CAXs should be able to interconnect an arbitrarily configured federation to an arbitrary CIS. Unfortunately, DiMuNDS 2000 did not address the issue of connectivity to CIS and therefore no conclusions or recommendations can be derived from DiMuNDS 2000 on this subject.

However, the following conclusions can be drawn:

- Technical requirements: For making a CAX based on federated simulation a success, a dedicated infrastructure is needed that enables the mapping of the data models of the simulation system and this CIS, respectively; furthermore, incorporating network specialists into the Federation Management Team at a very early stage is necessary to support scenario generation.
- Synergy Effects: Some of the findings above and recommendations below can be addressed within existing bodies, or establishing relationships between them;
- Academic Treatment: There are many theories of M&S, but very few address CIS. A dedicated theory of the representation of a modern(!) battlefield in terms of data models[14] would yield a benefit for CAX experiments;
- Standardisation Issues: Not only IEEE 1516 (HLA), but also other standardisation efforts, like the MDA of the OMG, should be taken into account for the establishment of distributed and federated applications (simulations as well as databases).

ACKNOWLEDGEMENTS

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[11] Recommendations in *italics*.

[12] The work may take [B-35] as a pattern.

[13] Action Item already captured from feedback of the SAS lecture series [A-11].

[14] From the viewpoint of information technology (IT), CIS are commonly organised in data bases; ideally these mirror a data model as the representation of the "real world".

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Mission Training through Distributed Simulation – Contributing to Warfighter Integration

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INTRODUCTION

MTDS

Mission Training through Distributed Simulation (MTDS) is directed at training aircrew for combined air missions in a virtual environment. It has been the subject of NATO RTO activities over the past five years (Tomlinson, 2000, 2002). Currently, the combined task group SAS-034/MSG-001 is preparing exercise First WAVE (Warfighter Alliance in a Virtual Environment), to be held in 2004. Six nations plan to make available simulation assets and other resources to conduct a COMposite Air Operation (COMAO). The objectives are, among others, to demonstrate the potential of MTDS and to propose a plan for further implementation and exploitation of MTDS in NATO and the nations. In this paper, the MTDS concept is described, and the activities of NATO in this area are presented. The text then focuses on Exercise First WAVE and the Modelling and Simulation issues involved in this effort. The paper finishes with conclusions drawn over the past five years.

Distributed Simulation

The term "distributed simulation" can mean many things to many people. In the present context, distributed simulation is about using modern networking technology to join together a collection of compatible advanced real-time pilot-in-the-loop flight simulators, plus other simulations, located at separate sites, in order to create a shared virtual "battlespace" in which all components, including command and control elements such as AWACS, can conduct multinational operational training and mission rehearsal tasks.

This is illustrated in fig 1, which features a variety of aircraft types (mostly represented by simulators but some could be computer generated) from a range of NATO nations, linked together via communication networks such that each simulated aircraft flies in the same shared "battlespace". The aircraft and mission simulators need to be complemented by databases representing a shared geophysical environment, including weather, and a shared tactical environment representing threats as well as elements of own forces. This concept could be described as a "distributed training environment". A crucial feature is the provision of a Tactical Control Centre shown as an artist's impression in the centre of fig 1, from which the entire exercise is controlled and managed.

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

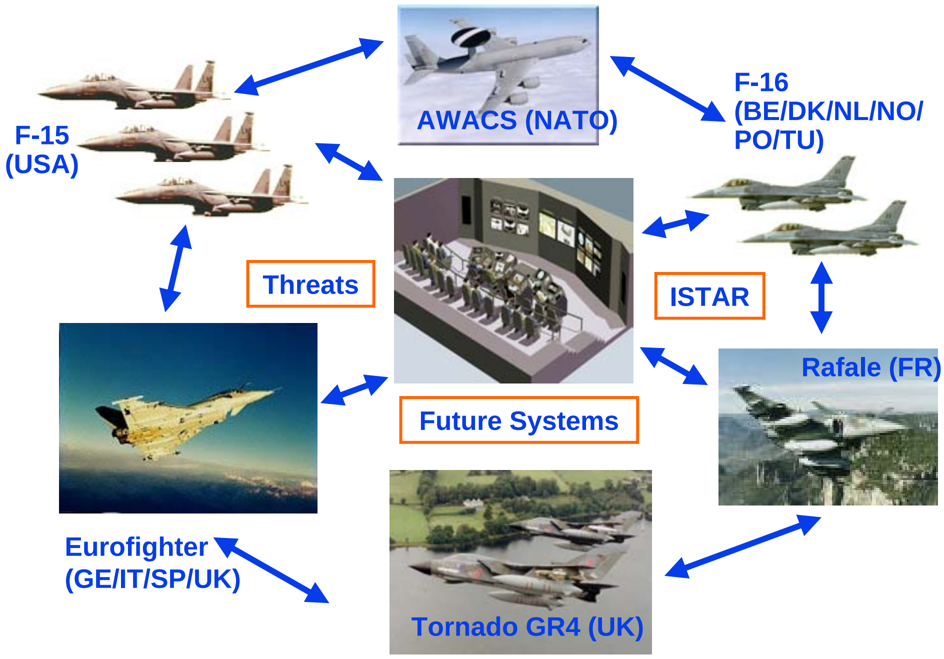

Figure 1: Distributed Training Environment.

Warfighter Integration

As concluded by the initial MTDS study (SAS-013) mentioned below, MTDS has great potential for NATO to enhance NATO's operational effectiveness to conduct composite air operations (COMAO). MTDS will contribute to integration of warfighters of different nations and with different roles in the operation. MTDS provides them with the opportunity to train together in a virtual environment. The environment is complementary to the sparse live flying occasions where NATO COMAOs can be trained. MTDS can provide a rich and complex operational environment and can expand the scope of training to include the chain of command, including real-time targeting and Command and Control. While training is the current aim, as the capabilities of the simulators evolve the networked simulators will gain the potential for mission rehearsal.

NATO BACKGROUND

Composite Air Operations

Air missions in a NATO context now focus extensively on operations where 20 to 40 or more aircraft fly in a package to strike a specific target or a set of targets. The composition of any package is based on the type of target, the expected threat during the mission and the level of destruction desired on the target.

Such a mission is referred to as a Composite Air Operation (COMAO). COMAOs are defined as "operations interrelated and/or limited in both time-scale and space, where units differing in type and/or role are put under the control of a single commander to achieve a common, specific objective" (AIRCENT manual 80-6 "Tactical Employment"). In this context, some typical roles are: Strike Attack, Air Defence, Offensive Support and Reconnaissance. Support roles include Airborne Early Warning, Electronic Warfare and Air-Air Refuelling.

A COMAO package will comprise aircraft in defined formations performing specified roles. A specific COMAO may also be referred to as a mission. Successful participation in a COMAO requires that aircrews be prepared to participate as effective members of a multinational force. These aircrews must be trained to operate as part of a collective combined force involving two or more teams from two or more countries. To meet this requirement, aircrews must master the skills necessary not only to employ their individual weapons systems but they must also master a number of collective, or inter-team, skills involving communication, co-ordination, planning, decision making, and situation assessment that will be exercised in a complex multinational environment.

COMAO training focuses on collective skills. Collective training may be defined as "training involving two or more 'teams', where each team fulfils different 'roles', training (to interoperate) in an environment defined by a common set of training objectives". A typical COMAO package composition is given in Fig 2.

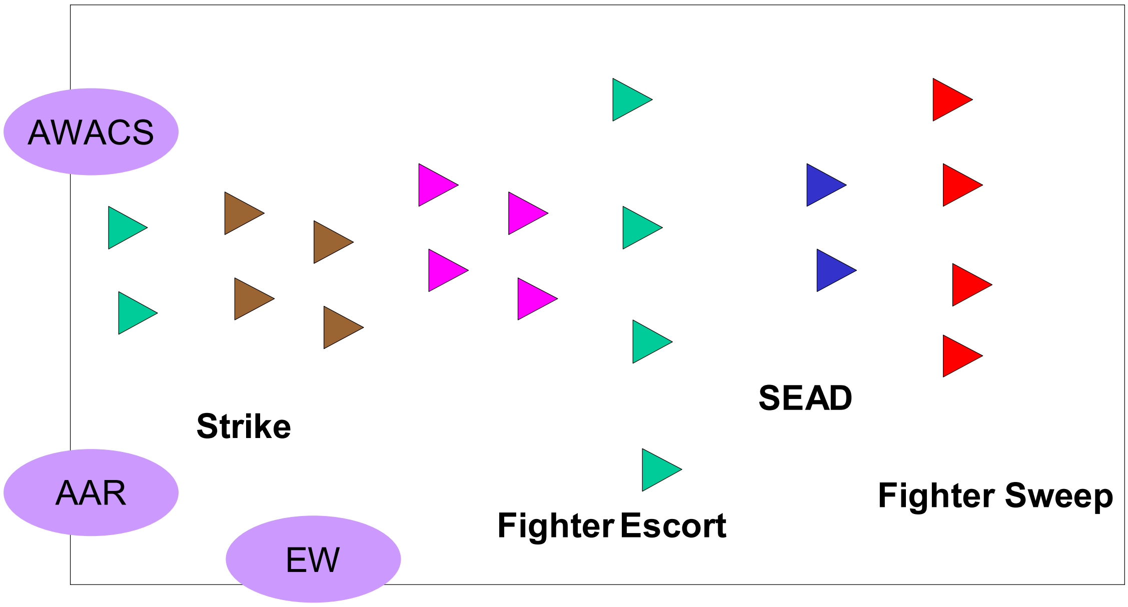

Figure 2: A Typical COMAO Package Composition.

A typical COMAO requires a lot of co-ordination and communication. Thus to achieve a successful outcome it is crucial that all participating aircrew adhere to the mission plan for the complete duration of the mission execution phase. However, not only the execution of the mission is important, also the process of Air Task Order (ATO) issue, mission planning, briefing and debriefing are essential elements in the training process for COMAOs.

NATO Training for COMAOs

NATO training for combined air operations is accomplished today through a variety of national programmes, including the US Red Flag and other exercises, and through the NATO Tactical Leadership Programme (TLP) based at Florennes, Belgium and also the annual NATO Air Meet (NAM) exercise. All these live flying exercises suffer from increasing constraints.

The Tactical Leadership Programme aims "to increase the effectiveness of allied tactical air forces through the development of leadership skills, tactical flying capabilities, mission planning and tasking capabilities, and conceptual and doctrinal initiatives". To do this, TLP provides integrated, multi-national flying and academic courses, seminars and conferences.

The impact of emerging and future systems is such that aircrew skills required to operate the next generation of aircraft are changing. The balance between flying skills and weapon system operation is now evolving to place greater emphasis on sensor manipulation, information management, situation awareness, decision making and communication. Such a change in emphasis generates a new training need for a complex tactical context in which sensor and weapon suites can be fully employed in association with other aircraft. Future operations will employ a "system of systems" in which single aircraft will themselves be part of an operational network. To ensure that aircrew will train as they will fight, they need opportunities to train with all appropriate and relevant assets.

NATO air forces need a virtual environment in which to acquire and sustain the skills needed to perform successfully as part of a multinational combined air force. This virtual environment needs to be inexpensive enough to be used frequently, be readily available at home station or some other appropriate location, and be secure enough to be used without revealing operational details and tactics to unauthorised personnel.

SAS-013 Study

The NATO RTO Military Applications Study SAS-013 was established by the Studies, Analysis and Simulation panel because a combination of factors is making it increasingly difficult to conduct adequate and effective aircrew training through live flying, especially training involving a variety of aircraft types and roles. The factors forcing change include lack of airspace and adequate range availability, environmental and safety restrictions, security constraints, concern about consumption of aircraft flying hours and airframe life, pressure to reduce training costs and limited opportunities to practise co-ordination of critical multinational NATO air missions in a representative operational environment, complete with threats. Furthermore, peace-time constraints typically preclude full operational use of Electronic Warfare (EW) systems, deployment of defensive aids such as chaff and flares and firing of live weapons. Modern weapon system performance capabilities and the growth of data links are also extending the "tactical reach" of an air package. Thus, aircrew combat training in the 2000-2010 time frame will need to be far different from the training of the 1990s, with emphasis on higher order weapons system employment skills requiring co-ordination, communication, and complex judgement.

The objective of the SAS-013 Study was "To assess the potential of advanced distributed simulation to complement live flying training in order to enhance NATO capability to conduct combined air operations", strong emphasis being placed on understanding the NATO operational environment and on how NATO training for combined air operations is accomplished today.

Placing mission training at the heart of the study emphasised that the study was not technology driven but focused on military need and preparation for operational capability. The study assumed that aircrew – pilots, navigators, and all weapons and mission system operators – participating in mission training for combined air operations possess the basic individual and team skills needed to be categorised as "combat ready". Such aircrew must then master the collective skills necessary in multinational operations as part of a larger unit involving two or more teams from two or more countries.

SAS-038 Symposium

A further RTO activity covering MTDS was the symposium (SAS-038) on "Air Mission Training Through Distributed Simulation (MTDS) – Achieving and Maintaining Readiness", held in April 2002 in Brussels. This NATO symposium aimed to enhance the NATO community's understanding of distributed simulation and its potential to enhance readiness training for NATO aircrews. Most NATO countries have ongoing research and acquisition programmes involving advanced distributed simulation. These programmes provide the foundation for a multinational training capability that will significantly enhance the readiness of NATO aircrews to conduct combined air operations. This Symposium brought together military commanders, the military user, the training community and the simulation industry to participate in a forum for discussion of the military requirements for multinational aircrew mission training in NATO and of the potential application of advanced distributed simulation.

MTDS Task Group MSG-001/SAS-034

To make progress with MTDS in NATO, two task groups to develop and demonstrate the concepts of MTDS have been formed. These task groups (SAS-034 and MSG-001) are sponsored by the RTO Studies, Analysis and Simulation panel and by the NATO Modelling and Simulation Group. The principal aims are:

- to increase awareness amongst the NATO military community of the potential of MTDS
- to conduct a demonstration training exercise to show the potential benefits in NATO of multinational mission training through distributed simulation
- to establish a set of guidelines, procedures and standards based on the NATO Modelling and Simulation Action Plan
- to propose further actions needed to implement and exploit MTDS in NATO and the nations

The task groups are working jointly, and are referred to as the "MTDS task group" in the remainder of the paper.

The MTDS task group is composed of five different task teams. Each of these teams focuses on an aspect of the exercise:

- Operations and training
- Technical
- Security
- Assessment
- Awareness

A steering group heads the task group. The steering group is made up of the National representatives of the participating countries, the chairmen of SAS-034 and MSG-001 and the leaders of the task teams mentioned above. A full-time program manager, sponsored by the USA, manages the entire effort.

EXERCISE FIRST WAVE

Goals

The main effort of the MTDS task group is to set up and conduct Exercise First WAVE (Warfighter Alliance in a Virtual Environment). The exercise will be designed to fulfil the overall objectives of the MTDS task group as stated above. More specifically, the top-level aim of the exercise is to create a distributed simulation environment in which warfighters can conduct a Composite Air Operation in order to demonstrate and assess the potential of NATO MTDS. The environment will be designed and developed in accordance with the HLA Federation Development Process (FEDEP). Apart from the main objective to demonstrate and asses the training value of MTDS, Exercise First WAVE will be used to facilitate investigation into the three key areas Exercise Management, Interoperability (including security) and Computer Generated Forces.

The MTDS task group plans to conduct Exercise First WAVE in the first half of 2004. The exercise will have a duration of five days. At the time of writing this paper, the scenario and the implementation of the

Exercise federation are being developed. All participants have agreed on a User Requirements Document (URD). The information in this part of the paper is based on the URD. However, no definitive implementation plan has yet been established, and not all potential players have committed. Therefore, the description that follows may be subject to change as plans evolve.

Scenario

The scenario is based on a COMAO operation over a generic, Balkan-type area. Fighters in a sweep role will head the package. They will be followed by Suppression of Enemy Air Defence (SEAD) aircraft and fighter-bombers with embedded escort. Operational aircrew in virtual (man-in-the-loop) simulators will fulfil these blue force roles. Virtual fighters will also protect a blue AWACS and provide laser designation. A ground-based FAC will also be present in the scenario via a virtual simulator.

The scenario also includes a real-time targeting loop, planned as follows. At a moment in time, a virtual JSTARS notices movement of an enemy vehicle on the ground. Then a UAV is directed to the spot for reconnaissance and as the vehicle is classified as a threat to the COMAO package one or more of the fighter-bombers in the package is tasked by AWACS or CAOC to eliminate it.

Air Tasking Orders (ATOs), Air Co-ordination Orders (ACOs), Rules of Engagement (ROEs) and Special Instructions (SPINS) will be provided to ensure that the mission environment is as similar as possible to the operational environment. Also the development of a credible Intelligence Picture will be essential to fully immerse participating aircrew in the exercise scenario. The Intelligence Picture will explain the political developments that had led to the conflict and, amongst other considerations, will outline the Order of Battle (ORBAT) and the competency/morale of participating forces.

Participants

Participating nations are Canada, France, Italy, The Netherlands, the United Kingdom and the United States of America. Apart from the air forces in most of these nations, industry and Research and Technology Organisations participate in the preparations for Exercise First WAVE. These participants plan to commit different kinds of assets, personnel and technology to the exercise. Currently, this RTO activity relies entirely on voluntary contributions of the participants.

THE DISTRIBUTED TRAINING ENVIRONMENT

Introduction

The federation to be developed for Exercise First WAVE provides a virtual environment to train composite air operations. This environment uses simulation and exercise management assets present at geographically separated sites in multiple countries. These sites are connected via a Wide Area Network (WAN) to form a distributed training environment.

Key elements of this distributed training environment (DTE) are illustrated in Fig 3. As illustrated in the figure all these elements are directed at supporting the training objectives for a particular exercise. The separate elements of the DTE as shown in the figure are elaborated in the paragraphs below.

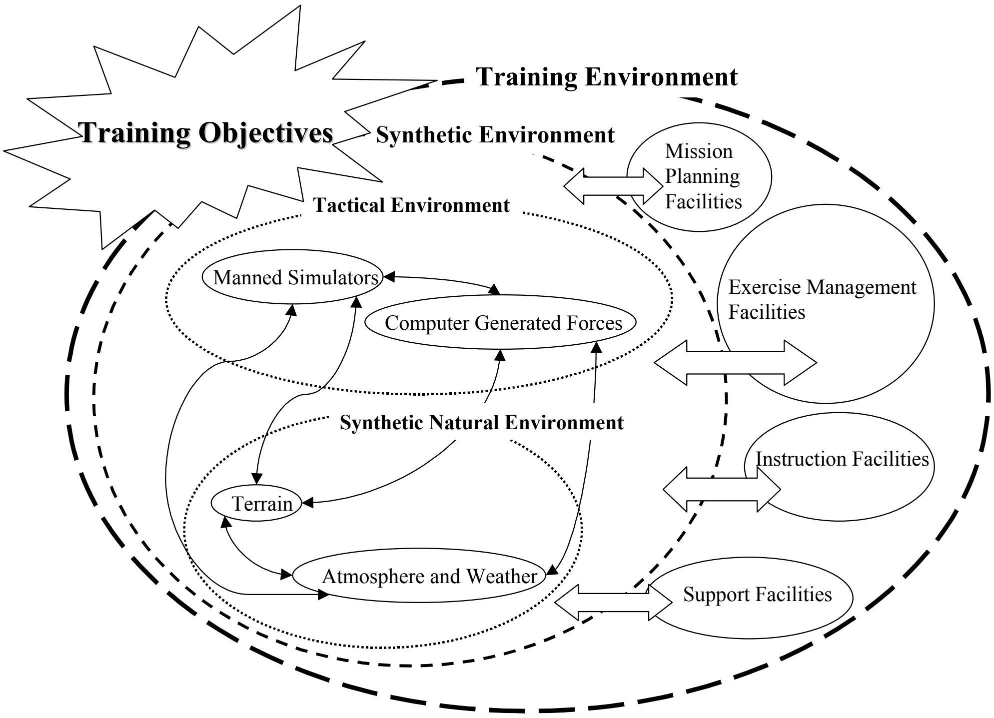

Figure 3: Elements of the Distributed Training Environment.

Training Objectives

As the exercise will be directed at training value, the federation will be developed to create a complete training environment. Not only the execution of the mission, but also the planning, briefing and debriefing will be facilitated. The high-level training objectives for the exercise will be:

- To practise daytime COMAO procedures employing fighter escort/sweep, AAR, SEAD, RECCE and AEW in a hostile environment
- To exercise procedures for defensive operations with Fighter Areas of Responsibility (FAORs) and point defence tasking
- To employ electronic warfare resources in support of offensive and defensive air operations
- To plan and integrate a multinational COMAO in a defined threat environment
- To brief a COMAO package generated from dispersed locations
- To conduct mission debriefs
- To engender efficient team-working skills between Nations and differing elements of the COMAO package
- To a develop a tactical appreciation of real-world threats
- To expose aircrew to situations to which they would not normally encounter in a peacetime environment
- To establish lessons identified

To the maximum extent possible, these training objectives will be used as a basis of assessing the training utility of the MTDS demonstration.

Synthetic Natural Environment

The Synthetic Natural Environment (SNE) represents the geophysical environment of the mission space, i.e. terrain and natural features, as well as 3D cultural features, together with the atmosphere and the weather. The SNE has to be represented well enough in the visual system and the sensors to serve the training objectives of the exercise, and to provide a maximum sense of immersion to the pilots.

The terrain database will consist of terrain elevation data and photo imagery. The goal is to have the entire playbox with at least five metre image resolution all over, with a 20-mile radius circle around the target area rendered with one metre resolution imagery. Located inside this 20-mile radius circle will be three desired target sets to be used in the MTDS exercise. The targets will be relevant to the type of scenario and will include ammunition and fuel depots, radar facilities, airfield installations etc, represented by 3D cultural features.

As the different participating simulations use various standards for visual and sensor databases, correlation of the databases becomes a significant issue. Producing a correlated SNE in the different formats is a task that requires a lot of effort. For Exercise First WAVE the SNE will be based on a database provided by Canada.

For training of time-critical targeting a mobile surface-to-air missile system will be included in the target set. At this point in time it does not seem feasible to integrate complex weather effects between all the participating simulators. For this reason, the weather will be no cloud and unlimited visibility.

Tactical Environment

The Tactical Environment defines the characteristics of, and performance for, all tactical entities which act on and react to each other and with the Synthetic Natural Environment.

The tactical environment will consist of manned (virtual) simulators and computer-generated forces. With some exceptions, the blue forces are manned simulators, and the red forces are CGF. The virtual simulators are a mix of operational simulators (currently used by aircrew for national training) and research simulators. Most CGFs will be generated by one central simulation package. An exception will be a few computer generated wingmen in the blue COMAO package, which will be simulated by the software integrated with the manned simulators to which they are attached. The red forces include air and ground threats. They will be programmed in such a way that they both support the training objectives and act realistically. Apart from these CGFs, the red force will have two manned fighter simulators.

Trigger events will be injected into the scenario during mission execution. These events are intended to provoke blue force interactions and promote training in the area of mission critical or time critical targeting. Trigger events will be planned in advance.

Interactions and Sensors

Interactions and sensors are a fundamental element of the distributed training environment. They provide the mechanism that enables one entity to know about the existence and behaviour of another entity. Interactions exist between the different tactical entities, and between a tactical entity and the geophysical environment. Interactions can be defined in various categories. Exercise First WAVE will facilitate radar, IR and visual interactions, physical contacts and voice communication. Within some flights, datalinks between aircraft will be simulated. No datalinks between flights and to/from AWACS are planned to be simulated. These interactions are all embodied in models, meaning that an interaction cannot exist unless one or more models incorporate it and exchange information about it.

Interactions between simulations are defined in the Federation Object Model (FOM). The sensors and weapons of most aircraft will be used as-is in the participating simulators. As far as can be judged at this moment, weapons and sensors of the participating simulators are modelled adequately for participation in Exercise First WAVE.

Exercise Management, Instruction and Planning

Setting-up, controlling and using a network of simulations as a training tool is a significant activity. An exercise scenario that facilitates the training objectives has to be designed, implemented and tested. During the training period, the environment must allow the trainees to do all planning, briefing, execution and debriefing activities necessary to receive maximum benefit from the COMAO mission. The personnel that assures that the training process proceeds according to the requirements is often referred to as the white force.

The individual sites will be connected not only during the execution phase, but also during the planning, briefing and debriefing activities. For planning, the sites will use their organic planning facilities. Briefing will be facilitated using interconnected interactive whiteboards and voice, so that the mission commander can brief all crews at the same time. For debrief, a distributed playback system will be used. This allows the mission commander or the white force to do a synchronised playback on a Plan View Display, including all voice communications. In live exercises this has proven to be a very effective way to highlight the lessons to be learned by the participants of the COMAO. These facilities may be supplemented by a video connection.

Additional Support Functions

Additional functions to support the exercise will be provided. They include the ability to set up and monitor the exercise in a technical sense, such that no trainees or members of the training staff are confronted with technical issues that would not occur in a live exercise. Provisions for management of the network and of security will also be made.

Network

An obvious requirement for a distributed training environment is a need for a wide area network with sufficient bandwidth to support real-time man-in-the-loop simulation and all the data that needs to be shared.

The current plan is to make use of an ATM cloud infrastructure for interconnection of the sites in the different countries. A portal will provide access to the network. This rack of equipment contains, amongst other devices, routers and an encryption device. It also includes a computer with software to interface a common data exchange standard with the local standard of interoperability of the different sites. The portal interfaces with both HLA and DIS systems. A portal will be present at each site or as the central node within a country. Some countries will use national networks to connect the different sites to each other and to the portal.

Security and Releasibility

The exercise First WAVE will be classified. This implies that the participating sites will be accredited for the applicable classification level, and that all data exchange between the sites will be encrypted. Furthermore, a project agreement between the participating nations has to be put in place in order to be able to release classified data over the network.

No multi-level security system will be used. This implies that all data present in the simulations connected over the network has to be releasable to all participants. For most participants this will mean that an arrangement must be made that allows the crews to obtain enough training value and yet will not reveal nationally classified data, e.g. accurate weapon parameters.

Security procedures require considerable time to establish. Therefore, a sound security plan is one of the first products that has to be produced for any exercise including networked classified simulations.

Fair Play

One of the principal considerations in a networked exercise is that it should enable a fair fight chance to every participant. This issue must be addressed early in exercise development. It means that the outcome of an exercise should be primarily determined by the characteristics of the weapons systems and human behaviour (tactics), and not by limitations or artefacts in modelling and simulation systems. It does not mean that every participant should have equal capabilities, but rather that whatever the results would be in the real world, those results should be accurately reflected in the simulation.

It must be realised that the capabilities of each networked simulator will determine its role and degree of participation in an exercise. For example, if the simulation of a particular aircraft sensor is not according to the actual behaviour of that sensor, it may not be allowed to use it in the virtual environment. Another example is a limited field of view of a participating simulator.

OTHER INITIATIVES

As evidence of the growing interest in distributed simulation for mission training, the SAS-013 Study identified numerous examples of national initiatives relevant to MTDS, including training system procurements, research and demonstrations.

Procurements of a new generation of advanced aircrew training systems, with the potential to be part of a distributed simulation mission training exercise, are in progress in many nations. These include:

- In the USA, the USAF Distributed Mission Training (DMT) Programme for Air Combat Command, with F-15C 4-ship simulators installed at Eglin and Langley AFBs in 1999 (Olson, 2002), an E-3 MTC in 2001 and two F-16 MTC sites due in 2002 (Bills & Burkley, 2002). These constitute the first steps in achieving a vision of a “Joint Synthetic Battlespace” by 2010.
- In the UK, a new generation of fast jet mission simulators for the Tornado GR4 (RAF), and Eurofighter (RAF) and, for the helicopter force, the WAH64 Apache Longbow (Army) mission simulators and the Medium Support Helicopter (RAF) simulators. All of these training systems have the potential to be linked to a wide area network.
- In Canada, plans for the CF-18 Advanced Distributed Combat Training System, part of an Advanced Distributed Mission Simulation concept.
- In France, the Combat Training Centre (CTC) at Mont de Marsan (Gardes, 2002).
- In the Netherlands, Norway and Belgium, F-16 MLU Unit Level Trainers. These have the capability to operate in a network of four F-16s and a CGI station.
- Germany, Italy, Spain and the UK are procuring Aircrew Synthetic Training Aids (ASTAs) for the Eurofighter programme.

Such national assets as these are vital as core elements in a potential future NATO MTDS capability.

CONCLUSIONS

Conclusions drawn over the past five years of NATO activities in the field of MTDS include the following:

- Several nations use, implement or plan national Mission Training Centres of networked simulators to meet national training requirements.
- Combining these assets into a MTDS infrastructure has great potential to sustain and improve the capability of NATO to conduct Combined Air Operations when used in a manner complementary to live operations.
- Integration of dissimilar (legacy) simulators into a distributed training environment raises several interoperability issues, including:
  - Security and releasibilty: the training environment has to provide a good balance between maximum training value and national data release aims.
  - Synthetic Natural Environment: in particular correlated visual and sensor databases and weather representation are not easy to achieve over dissimilar legacy simulators.
  - Representation: the degree to which the simulator represents the capabilities of the real aircraft will influence the role that can be played in the mission.
- Exercise First WAVE is the first ever NATO effort to demonstrate and assess the training value of MTDS in air operations. The distributed training environment for Exercise First WAVE will support the mission planning, briefing, execution and debriefing activities of the trainees.
- The federation and the guidelines being developed for Exercise First WAVE will be a basis for further implementation and exploitation of MTDS within NATO.

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NC3A Simulation Support for Theatre Missile Defence Operations in NATO Exercise Cannon Cloud 2002 (CC02)

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ABSTRACT

This paper discusses modeling and simulation methods to be employed by the NC3A to support Theatre Missile Defence (TMD) operations in the upcoming Supreme Headquarters Allied Powers Europe (SHAPE) exercise Cannon Cloud 02 (CC02). The TMD operations are but a small part of a large, multi-corps, multi-CAOC (combined air operations centre) computer-assisted exercise (CAX) using the Joint Theatre Level Simulation (JTLS) operated at the United States Air Force – Europe (USAFE) Warrior Preparation Center (WPC) in Einsiedlerhof, Germany. The challenge for this exercise was determining how to integrate the detailed, entity-level simulations necessary to support active defence, passive defence, and time-critical and time-sensitive targeting functions of TMD operations with the aggregated movements of the larger JTLS environment.

The approach taken to the multi-resolution modeling problem was threefold. First, high-level architecture (HLA) methods were used to pass Tactical Ballistic Missile (TBM) events between JTLS, the Extended Air Defence Simulation (EADSIM) and NATO's Shared Early Warning (SEW) system to allow simulation interoperability. Next, in order to synchronize the detailed movements of TBM units in JTLS and the entity-level simulation Integrated Target Environment Simulation Tool (ITEST), identical movements were created for JTLS units. Lastly, civilian background traffic not represented in JTLS was geographically separated from the combat area. Discussions of this simulation integration are included in this paper, but owing to the

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exercise schedule, the results of the effort to minimize the multi-resolution modeling problem will be reported at a later date.

To integrate the simulations for CCO2, cooperation was fostered between two divisions of the NC3A, Allied Air Forces North (AIRNORTH), the Royal Netherlands Air Force (RNLAF), TNO (a Dutch organization for applied scientific research), and the seven-nation Coalition Aerial Surveillance and Reconnaissance (CAESAR) Project.

INTRODUCTION

NATO C3 Agency

The NATO Consultation, Command and Control Agency (NC3A) is located in two facilities: one in The Hague, Netherlands, and the other in Brussels, Belgium. The NC3A was formed in 1996 by the amalgamation of the former SHAPE Technical Centre (STC) and the NATO Communications and Information Systems Agency (NACISA); the NC3A is chartered to provide unbiased scientific advice and assistance to NATO military and political authorities. Additionally, the Agency plays a major role in developing, procuring and implementing cost-effective systems capabilities to support the political consultation and military command and control functions of NATO. The mission of the NC3A is defined in the charter of the NATO C3 Organization (NC3O)[1].

The mission of the NC3A is to:

- Perform central planning, systems integration, design, systems engineering, technical support and configuration control for NATO C3 systems and installations.
- Provide scientific and technical advice and support to the Strategic Commands and other customers on matters pertaining to operations research, surveillance, air command and control including theatre missile defence, electronic warfare and airborne early warning and control, and communications and information systems, including technical support for exercises and for unforeseen operations assigned to the NATO Military Authorities by the North Atlantic Council's Defence Planning Committee.
- Perform technical policy and standardization work in support of the NATO C3 Board and its substructure towards the development and maintenance of the NATO Interoperability Framework.
- Procure and implement projects assigned to it.

The organization of the NC3A consists of a General Management office, Executive Staff, a Director of Operations, and six Divisions. The Theatre Missile Defence (TMD) work discussed in this paper was performed by the Command and Control Systems Division, Command and Control Concepts and Architecture Branch[2], which serves as NATO's Centre of Excellence for TMD Battle Management Command and Control and Air-Ground Surveillance and Reconnaissance (AGSR). The overall exercise is managed by the Exercises, Design and Scenario Development Branch of the Operations Research and Functional Services (ORFS) Division.

[1] NC3A website http://www.nc3a.nato.int/ pages/frameset_org.html.

[2] Branch website http://www.nc3a.nato.int/ pages/ccsdiv/ccb/ccb_main.htm.

Operations Research and Functional Services (ORFS) Division

The mission of the Operations Research and Functional Services Division is to conduct scientific and technical analysis for SHAPE and its subordinate commands on a wide range of military operational and planning issues. These analyses range from broad studies of military concepts such as those relating to the new missions of SACEUR, to detailed examination of the performance of military units and support systems.

Exercises, Design and Scenario Development Branch

The mission of NC3A's exercise branch is to support NATO's Allied Command Europe (ACE) in the specification, development, implementation and evolution of a training and exercise organization. This organization makes use of the most advanced methods and tools available to perform its tasks of individual and collective training and exercise. Hence there is emphasis on assistance by automated systems in the preparation, conduct, observation and analysis of training events.

An evolutionary methodology of systems development is applied that relies heavily on user participation and experimentation. Methods of organization 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 incorporation of the TMD simulations represents an example of this policy. Further discussions are presented below under 'The Way Ahead'.

Command and Control Systems Division (CCSD)

The mission of the CCSD is to support overall system-level architectures, concepts and implementation of command and control (C2), battlespace management (BM), and intelligence, surveillance and reconnaissance (ISR) capabilities for air, sea, land, and joint operations, mainly at the operational and tactical levels. The Division consists of a Management and Project Support element, and five scientific branches.

Command and Control Concepts and Architecture Branch

The C2 Concepts and Architecture Branch consists of eight scientists and three scientific support staff, augmented at times by technical experts supplied by nations in order to support the work of the Branch. On behalf of SHAPE, this Branch is responsible for a number of activities, including:

- Definition of requirements for NATO's emerging air-ground surveillance and reconnaissance (AGSR) capabilities;
- Technical management of the Coalition Aerial Surveillance and Reconnaissance (CAESAR) activity;
- Definition of NATO's Theatre Missile Defence Battle Management Command, Control and Communications requirements.

In addition, on behalf of the Conference of National Armaments Directors, the Branch provides support to the NATO active Layered Theatre Ballistic Missile Feasibility Study.

The role of the Command and Control Concepts and Architecture Branch in the exercise is to provide the hardware, software and communications capability required to enable detailed simulation of TMD activity of suitable fidelity such that the training objectives of the Joint Theatre Missile Defence Cell (JTMDC) could be achieved. This task is further complicated by the integration with the aggregate Joint Theatre Level Simulation (JTLS), which provides the overall environment for the exercise. Figure 1 depicts the architecture established for the exercise.

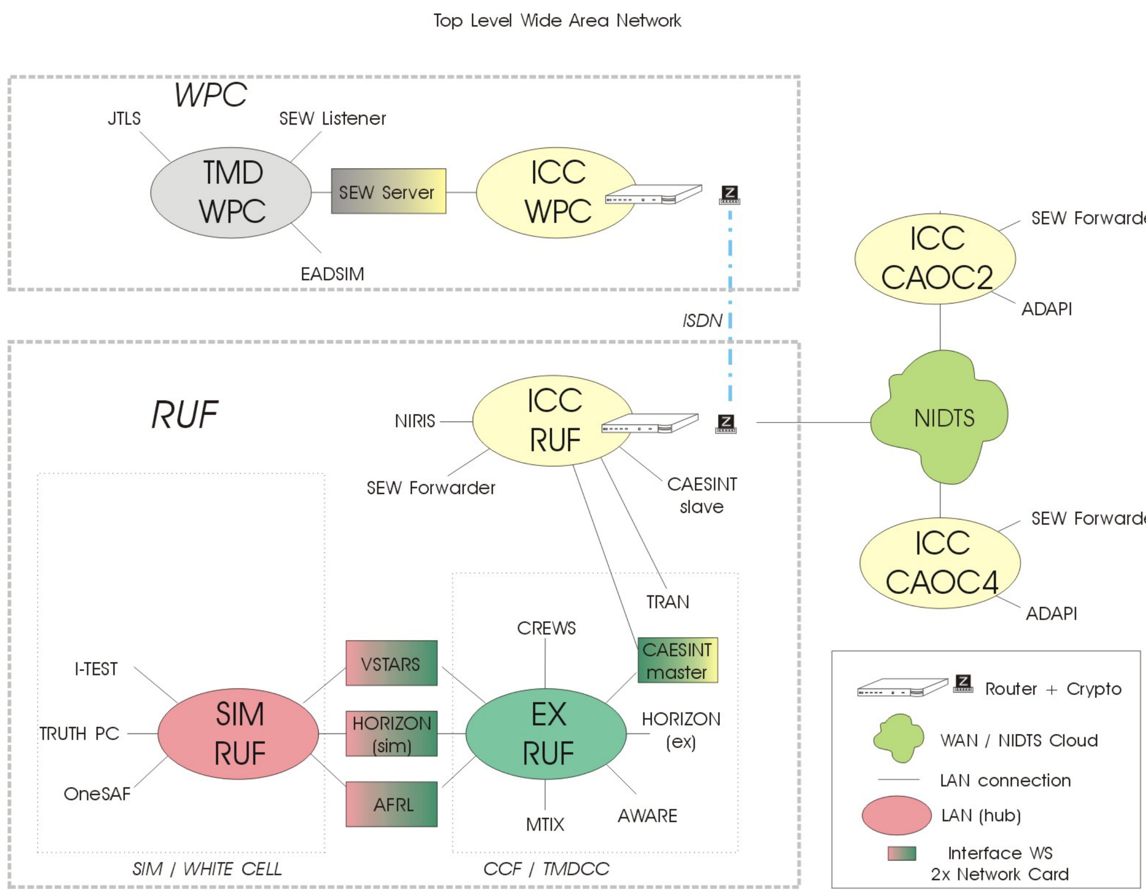

Figure 1: Exercise Network Architecture.

CANNON CLOUD 2002 OVERVIEW

CC02 is a large, multi-corps, multi-CAOC, computer-assisted exercise (CAX) that will be conducted at the USAF Europe (USAFE) Warrior Preparation Center (WPC) in Einsiedlerhof, Germany. The primary purpose of CC02 is to support higher echelon operational training for coalition forces in a large-scale, high-intensity conflict using the Joint Theatre Level Simulation (JTLS), which is an aggregate simulation that has served as the SHAPE-approved CAX simulation since 1995.

The scenario to be employed uses actual northern European terrain with fictitious national boundaries (see Figure 2). The Tactical Ballistic Missile (TBM) threats are operated by the coalition of Oliveland and Orania against the southern region of Montrena.

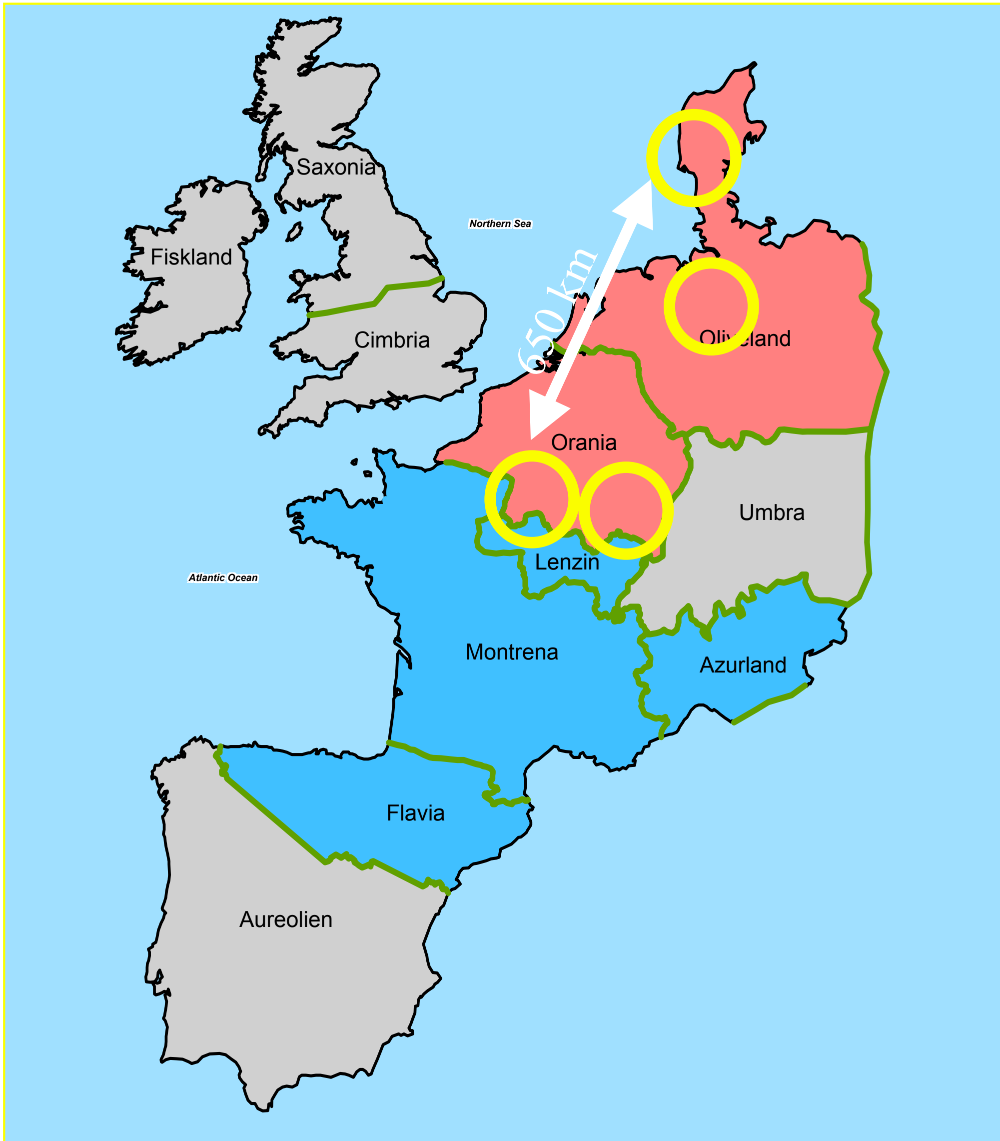

Figure 2: Cannon Cloud Scenario with TBM Areas of Operation.

The Joint Theatre Missile Defence Cell (JTMDC) will act as the hub of the Battle Management / Command, Control, Communications, Computers and Intelligence (BMC4I) capabilities required to coordinate conventional counter-force (CCF) and passive defence (PD) operations, and integrate these elements into the overall combat operations (see Figure 3).

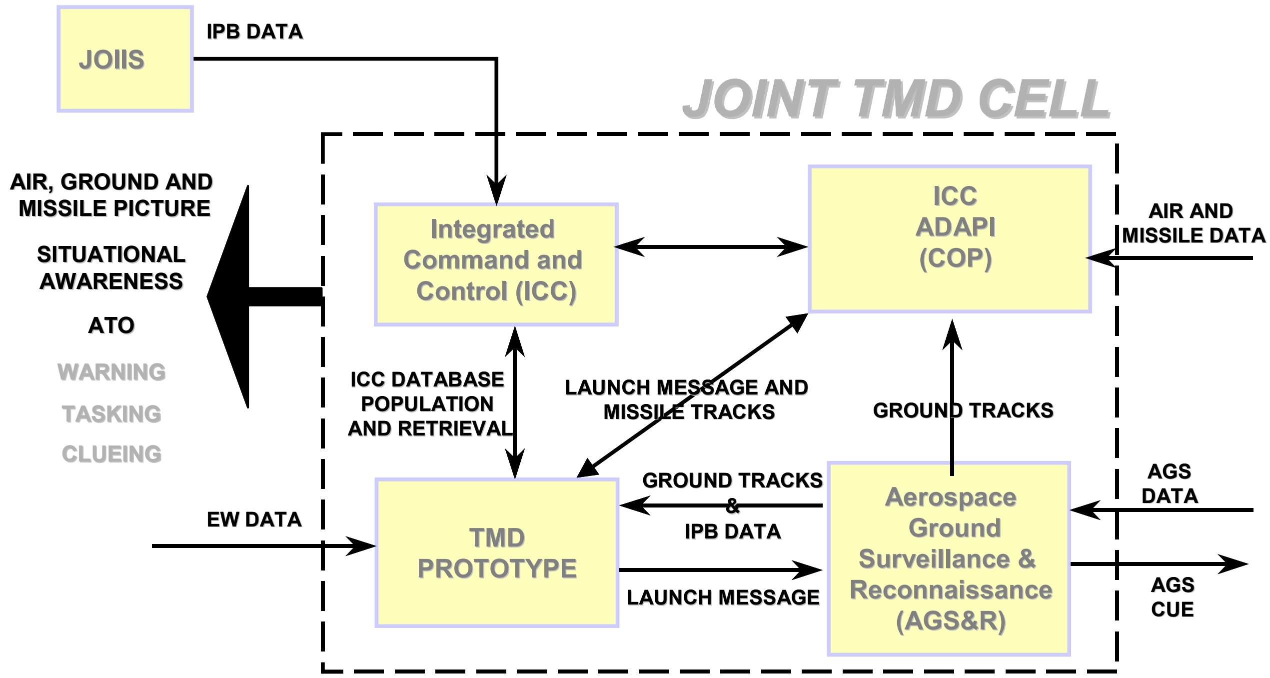

Figure 3: Joint Theatre Missile Defence Cell.

The objective of the TMD segment of Cannon Cloud is to provide a realistic TBM threat. The mission of the JTMDC is to protect NATO forces from TBM attack by conducting CCF operations against threat coalitions to ensure that threat TBM infrastructure and support systems can be destroyed prior to TBM launch.

JTLS Installation at the Warrior Preparation Center

The CC02 technical and exercise control nexus is at the WPC where over 200 workstations will be deployed running the JTLS simulation. Response cells for Corps and CAOC battle staffs operating in the field are colocated at the WPC with the exercise-directing staff and cells representing other forces and neutral entities depicted in the scenario. The Rupertsweiller Underground Facility (RUF), acting in perhaps its last NATO exercise, will serve as AIRNORTH's wartime command centre with exercise data fed to its command systems through the NATO communications infrastructure. There is no JTLS linkage to the RUF.

The Four Pillars of NATO TMD Doctrine

The four pillars of NATO's TMD doctrine are: passive defence, active defence, conventional counter-force (CCF) and battle management, command, control, communications and intelligence (BMC3I). Each of these elements of TMD doctrine will be employed in the exercise.

Passive Defence

Passive defence will be provided by the NATO Shared Early Warning (SEW) system. For the exercise, the SEW injector tool will create a launch event initiated by JTLS using a high-level architecture (HLA) listener. The launch warning data will then be forwarded to the SHAPE server via the secure CRONOS wide-area network (WAN).

Active Defence

Active defence will be provided at the WPC in conjunction with the Dutch/German combined exercise Constructive Optic Windmill (COW). The Royal Netherlands Air Force (RNLAF) will operate Patriot PAC-3, the German Air Force (GAF) will operate Patriot PAC-2 and the Royal Netherlands Navy (RNLN) will operate the Air Defence and Command Frigate (ADCF). The Extended Air Defence Simulation (EADSIM), provided by TNO-FEL, will provide simulations of both the TBM missile fly-out and the interceptor at the entity level. EADSIM, like the SEW injector, is linked to JTLS using HLA but with a more robust interface including missile inventory reduction and the resulting intercept result fed back into JTLS.

Conventional Counter-Force

Conventional counter-force operations require a representation of the radar-based Alliance Ground Surveillance (AGS) systems. The seven-nation Coalition Arial Surveillance and Reconnaissance (CAESAR) project provides simulations of the Canadian RADARSAT II, the Italian CRESO MTI helicopter, the French HORIZON MTI helicopter and the US Global Hawk UAV, Joint STARS, Predator UAV, P-3 (‘Hairy Buffalo’), and U2 ASARS 2. These surveillance systems will search for the launch systems and their associated infrastructure using Ground Moving Target Indication (GMTI) and Synthetic Aperture Radar (SAR) modes.

To support the level of detail required for the sensor simulations, the rear-echelon movements of TBM components, unit headquarters, and civilian traffic must be represented on an individual vehicle basis. Additionally, the AGS exploitation systems are becoming sophisticated enough in their ability to generate tracks that realistic movement and behavior must be reflected in the movements of the individual vehicles.

Entity-level simulation capability will be operated at the RUF using Trident Systems’ Integrated Target Environment Simulation Tool (ITEST). Scripted movements were generated that allow vehicle-level movements that reflect threat concept of operations (CONOPS). These scripts were also ported to the JTLS simulation as high-resolution units (HRU) so that identical movements will be portrayed in the overall exercise.

Battle Management, Command, Control, Communications and Intelligence (BMC3I)

The CAESAR project provides the battle staff of the JTMDC with advanced MTI and SAR exploitation systems used for target development. The dissemination of the exploited AGS data to the wider command and control information systems is performed through the transmission of Link-16 J-series messages (see Table 1) via the NC3A Interoperable Recognized Air Picture (RAP) Information System (NIRIS). CAOC-2 (in De Peel, NL) and CAOC-4 (in Messtten, GE) will be able to display ground track information on Integrated Command and Control (ICC) terminals operating the ADAPI (air defence air picture) software.

Table 1: Link-16 Messages Disseminated Using NIRIS

Message	Description
J2.2	Air Precision Point Location Indication (PPLI)
J2.5	Ground Precision Point Location Indication (PPLI)
J3.0	Reference Point
J3.2	Air Track
J3.5	Ground Track

NC3A and its sponsor SHAPE OPS have developed an information system that disseminates the RAP to various users, converts data between formats, provides record and playback capabilities, and provides specialized hardware components for security filtering and protocol matching.

NIRIS consists of both hardware and software components that can be mixed and matched to provide solutions to real-time data interfacing, distribution, and display of maritime, ground, air tactical, and TMD data.

The aim of NIRIS is to acquire, distribute and transform tactical data produced by radars and assembled by sensor fusion posts; tactical data contains near-real-time position information, airplane ID and information from the airplane transponders. The combination of several tactical data feeds can be displayed on a map and constitutes the RAP for the countries that are part of the network. For CC02, ground track information has been added to the NIRIS Link-16 message library allowing GMTI data to be displayed on ICC terminals using the ADAPI software.

INTEGRATION OF SIMULATIONS USING HLA

Simulation interoperability is currently perceived as the most cost-effective method of enhancing exercise environments. In particular, 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 recognized that this approach requires greater emphasis on 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 multinational context requires a substantial and sustained commitment by the participating nations and institutions.

The first step in the exercise planning process was to develop an architecture for the integration of the systems that would meet the requirements of the exercise and minimize the risk associated with the multi-resolution modeling problem. After several iterations the final architecture was developed (Figure 4).

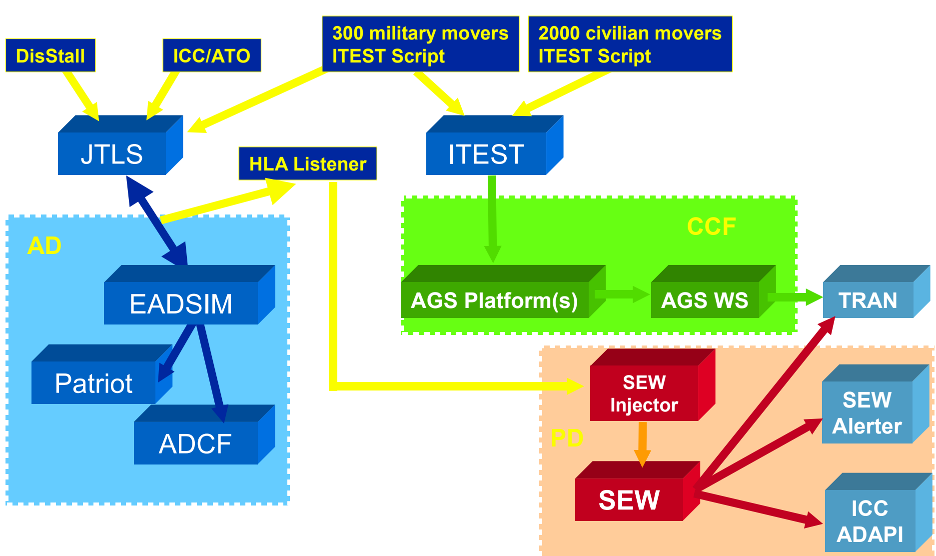

Figure 4: Interoperable Simulation Architecture.

The operation of aggregate and entity-level simulations is problematic and the topic of a great deal of research within the simulation community. NC3A has chosen the geographic separation technique to limit the conflict associated with multi-resolution simulation. Operationally this is appealing in that the TBM threat generally operates towards the rear area and the overlap area of coverage is minimized.

High Level Architecture (HLA) Testbed

In order to facilitate the integration of JTLS, EADSIM, SEW and the various AGS simulations, an HLA testbed was established in the NATO Alliance Ground Surveillance (AGS) Capability Testbed NACT (see Figure 5). This facility allowed the development and testing of the HLA components necessary to integrate the different simulations. The computer-aided software engineering (CASE) tool kit used was AEgis Technology Inc.'s HLA Labworks©.

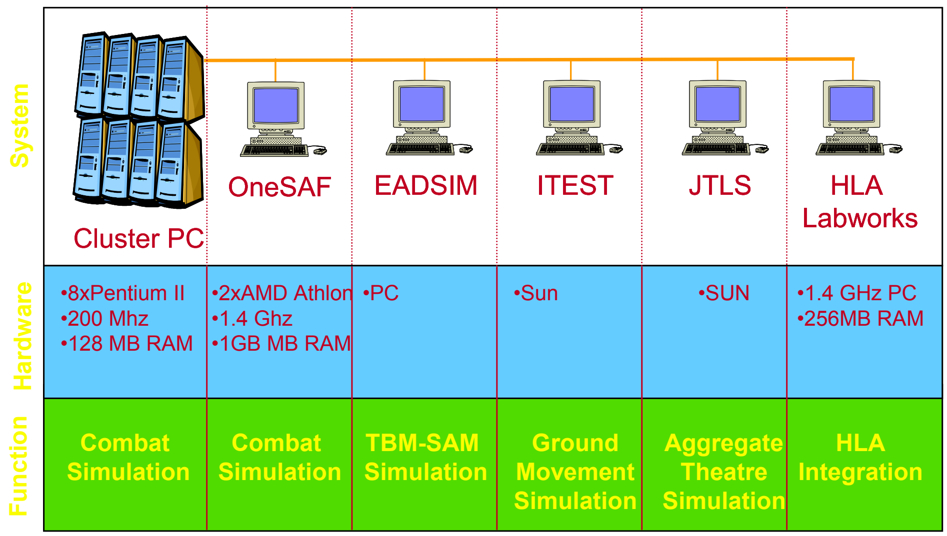

Figure 5: NC3A High-Level Architecture Testbed.

Active Defence

The Dutch national exercise Constructive Optic Windmill (COW) contributed the active defence portion of TMD operations for CC02. TNO-FEL, under contract from the RNLAF, developed the federation that allows simulation events to be passed between JTLS and EADSIM. JTLS issues the TBM launch command and EADSIM flies the missile. The RNLAF, the RNLN and the GAF will operate EADSIM to launch Patriot and SM-2 interceptors and the results of these engagements will be forwarded to JTLS to both update the interceptor inventories and implement the results of the engagement. Furthermore, satellites are simulated to produce the required launch-point prediction (LPP) and impact-point prediction (IPP) for the SEW system.

The development of the JTLS-EADSIM federation required more resources than were planned for. Despite previous integration efforts earlier in the year it appeared that the different implementations of HLA in the two simulations caused instability that was difficult to track down. EADSIM has the Agile FOM (federate object model) embedded within the software whereas JTLS appears to have been designed for a different, more homogeneous use of HLA. The federation was stabilized but it should be noted that the integration of disparate HLA implementations may present unforeseen challenges.

Passive Defence

NATO currently operates the Shared Early Warning (SEW) system, which receives satellite warnings of missile launches within NATO's area of concern. In past exercises[3] the simulated launches originated from the US North American Aerospace Defense (NORAD) system and the SEW data paths were used. For CC02 these are not being used. Instead an HLA listener was developed that detects the JTLS launch commands sent to EADSIM. This information is then fed into the SEW system using the SEW alert tool, which emulates the data from space-based warning systems.

The HLA listener was developed relatively quickly but the implementation revealed a minor problem within EADSIM that required a work-around. The identification tag used to link the missile to the launch event was mistakenly assigned the identification of the launcher, not the missile. This was resolved by waiting for subsequent entity state messages coming out of EADSIM. The time delay incurred waiting for the subsequent message with the appropriate data allows realistic simulation of the data dissemination process.

Multi-Resolution Modeling (MRM) Issues for the Conventional Counter-Force Mission

The conventional counter-force mission presents a challenge to the simulation architecture in that the sensor simulations providing the AGS coverage are engineering-level models requiring detailed entity-level movement, digital terrain elevation and features data. In order to represent the same TBM infrastructure movements in JTLS that the AGS sensors see, HRU scripts were generated that have individual launcher movements that are synchronized with the AGS simulation (see Figures 6 & 7).

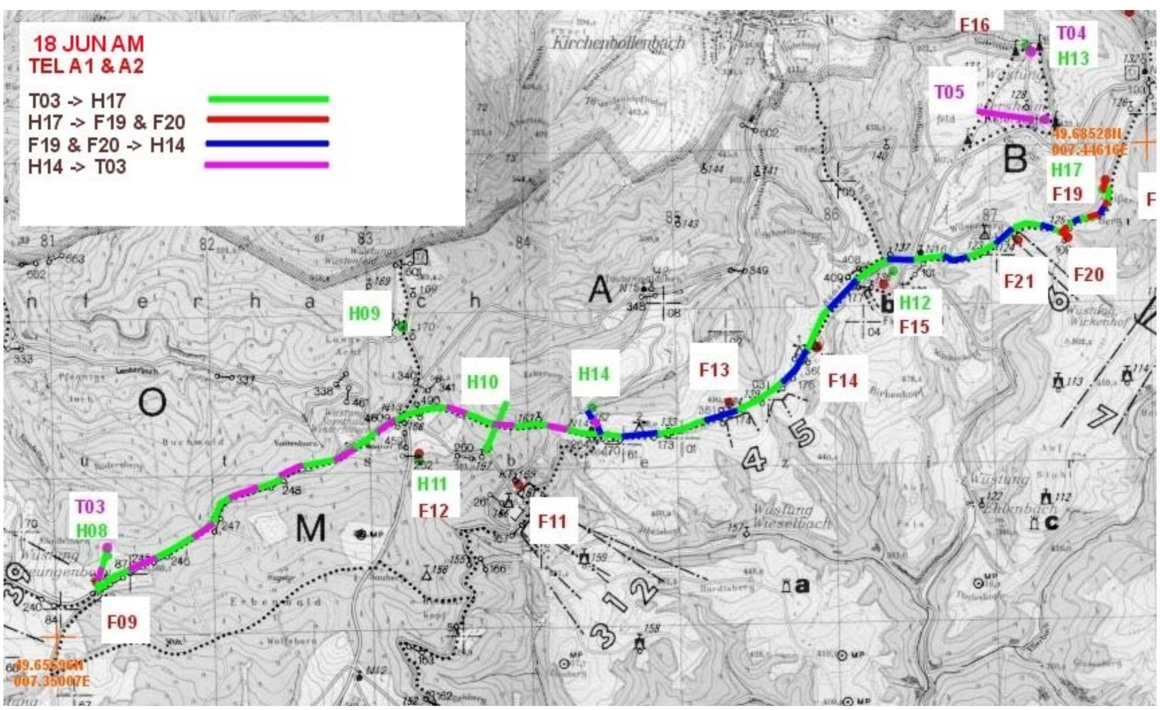

Figure 6: Detailed TBM Force Movements Used for AGS Simulations.

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[3] 'NC3A Simulation Support for NATO Exercise Clean Hunter 2001', David Taylor, paper presented at CCRTS in Monterey, California, June 2002.

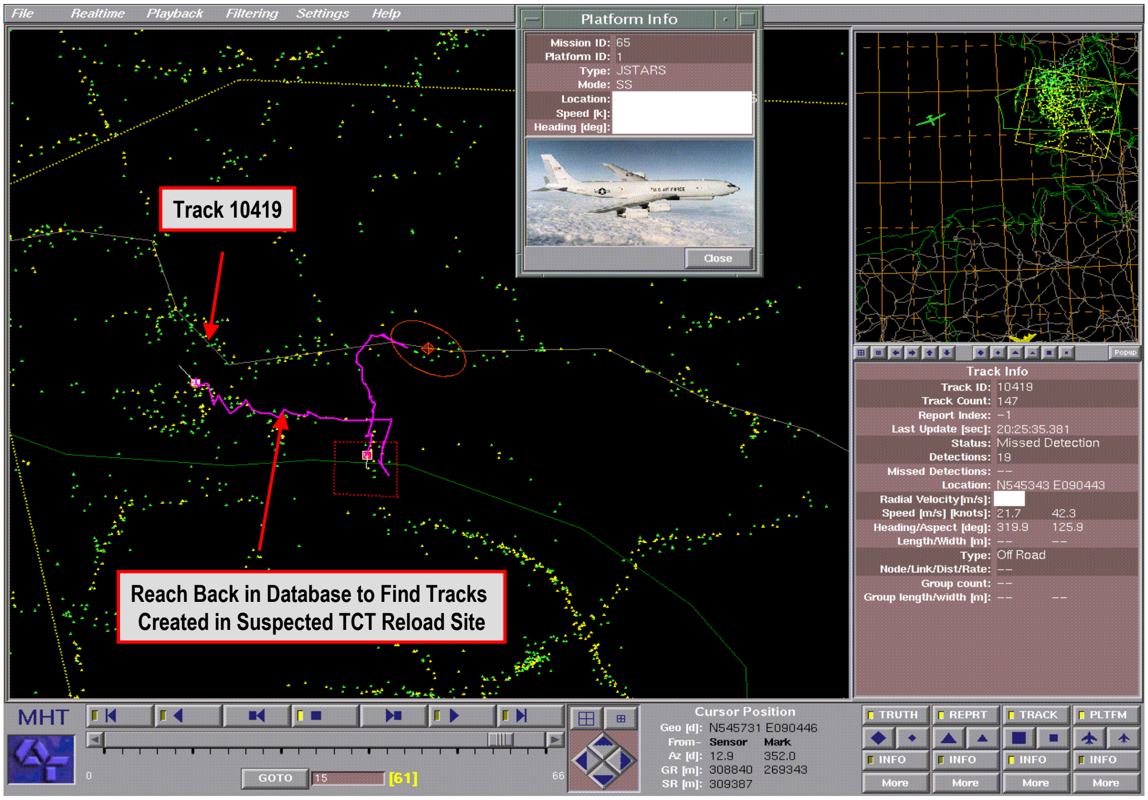

Figure 7: Example of Exploited MTI Data.

The risks associated with MRM were not completely avoided. Although the TBM units operate towards the rear it is necessary for JTMDC training that civilian or background traffic be represented in the TBM area of operations. Although JTLS can represent civilians and refugee movements, it was decided that civilian traffic would not be scripted for this exercise.

Future research will investigate the RPRFOM (real-time platform reference FOM) and HLA gateway as a means to allow position reporting to JTLS rather than having to duplicate objects in the battlespace.

NATO Alliance Ground Surveillance (AGS) Capability Testbed (NACT)

In November of 1995 the Council of National Armaments Directors (CNAD) decided that NATO should acquire an AGS capability based on NATO-owned-and-operated core capabilities supplemented by interoperable national assets. The NACT was then established with the support of NC3A, SHAPE and six nations and provides the NATO nations with a unique international testbed for research and development of interoperable AGS systems in support of NATO AGS requirements.

The NACT consists of NATO and nationally supplied hardware and software that allows systems to be interconnected for the purposes of enhancing development efforts, performing experiments, providing demonstrations and participating in exercises. The NACT consists of two local-area networks (LAN), a simulation LAN using the Distributed Interaction Simulation (DIS) protocol and an exploitation LAN in which data is passed in NATO EX and Link-16 message formats (see Figure 8).

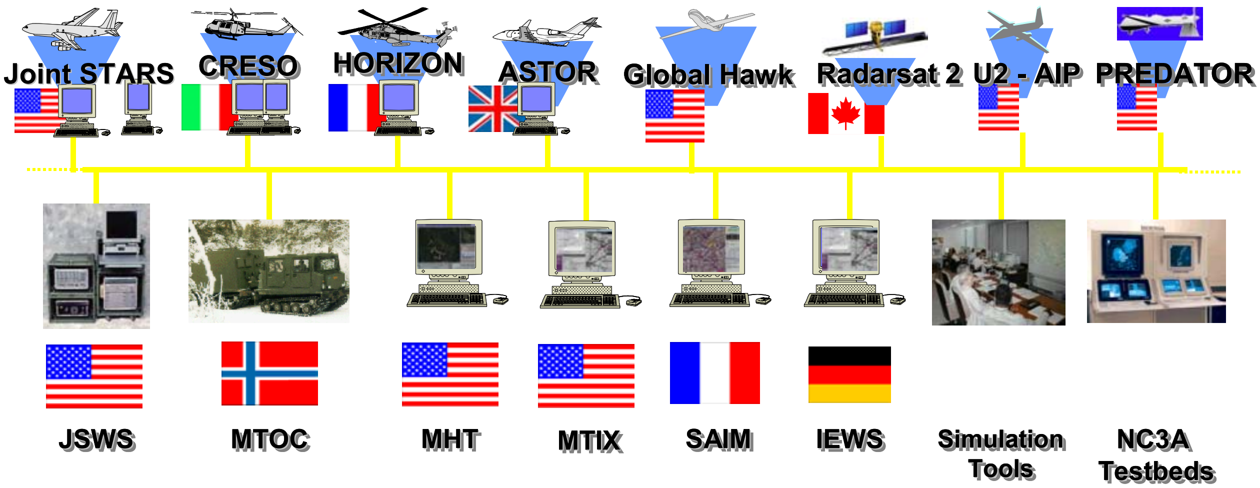

Figure 8: NATO Alliance Ground Surveillance (AGS) Capability Testbed.

The NACT is a unique facility in that it is a true international interoperability testbed allowing currently seven participating nations to exchange ISR data. It is difficult for nations to develop inter-service testbeds, and developing international facilities is even more difficult. The importance of such testbeds for building coalition military capability was described by Sir Robert Walmsley, chief of defence procurement and chief executive of the UK Defence Procurement Agency: “Interoperability is a key determinant of any coalition’s capability. The increasingly important role of information in military operations … is hugely more important today in the thinner battlefield. This testbed activity is essential (absolutely sine qua non) to interoperability.”[4]

Achieving Interoperability

The key element in achieving interoperability across this diverse collection of AGS systems is the use of the NATO EX message format[5]. The precursor to the Common Ground Moving Target Indicator (CGMTI) message[6], NATO EX consists of a header and three segments (MTI, SAR and ESM). By reformatting data at the ground station, information from all of the sensor and exploitation systems can be shared without having to consider proprietary datalink issues.

CAESAR Project

The Coalition Aerial Surveillance and Reconnaissance (CAESAR) project was established as a seven-nation project in January 2001 and named the US’s Advanced Technology Concept Demonstration (ACTD) of the Year.

Member nations include Canada, France, Germany, Italy, Norway, the United Kingdom and the United States. For Cannon Cloud, a limited set of CAESAR participants will support the conventional counter-force mission.

4 ‘Roadblocks to Interoperability Frustrate Coalition Communicators’, Signal, November 2000, p 41.

5 NC3A Technical Note 732, ‘Formats for the Representation of Alliance Ground Surveillance (AGS) Pre-Exploitation Data Types’, P.J. Lenk, October 1998 (NATO Unclassified).

6 See also STANAG 4607 (CGMTI) draft version 1.01d5a, 27 April 2001.

A true coalition effort, CAESAR has a central objective of developing the operational concepts, tactics, techniques and procedures, and technology that will enhance the interoperability of existing and planned coalition ground surveillance assets. Based on simulated experiments and live-fly exercises, the project provides a vehicle to develop, demonstrate, evaluate, and transfer into existing hardware the ability to:

- Disseminate Ground Moving Target Indicator (GMTI) and Synthetic Aperture Radar (SAR) data and exploitation products from multiple platforms and exploitation capabilities in a common format;
- Provide enhanced exploitation of GMTI and SAR data for improved correlation, location accuracy, tracking continuity, and tracking accuracy;
- Archive, search, and retrieve SAR and GMTI data using a distributed database architecture;
- Produce data or displays to support the development of a Common Operational Ground Picture and/or Joint Tactical Ground Picture;
- Assist in evaluating the effectiveness of multiple assets in supporting Requests for Information and their impact on Mission Tasking and Planning;
- Migrate GMTI and SAR exploitation to an Internet-browser-based, hardware-independent solution;
- Provide more accurate representations of simulated ground movement to support development and training.

In addition, the project provides the context for developing, implementing, evaluating, and refining the operational processes required to effectively task, plan, operate, and exploit coalition ground surveillance assets to support Intelligence Preparation of the Battlefield (IPB), Indications & Warning (I&W), Situation Awareness (SA), and Targeting.

THE WAY AHEAD

The results of the TMD portion of CC02 will be assessed in a number of ways. ISR management, the CCIRM (collection and coordination of intelligence requirements management) process and the effectiveness of locating critical elements or TBM infrastructure will comprise the top-level assessment for a 'lessons learned' report to the NATO Modeling and Simulation Group (NMSG 006) on Extended Air Defence C2 Interoperability.

CAESAR Project

The CAESAR project will evaluate a questionnaire that is to be given to various operators for subjective assessment of the operational value of interoperable AGS assets in support of time-sensitive targeting. The questionnaire itself will be revised and updated in preparation for possible CAESAR participation in Roving Sands 2003.

More detailed assessment of technical interoperability will be performed under the CAESAR project with network bandwidth metrics, message format compliance and possible simulation anomalies.

TNO-FEL

The successful demonstration of linking exercise simulations using HLA provides an opportunity for future participation of the Dutch armed forces in larger NATO exercises that include TMD operations.

NATO Perspective

The creation of the NATO-Russia Council with its emphasis on TMD and the progress of the NATO TMD Feasibility Study should provide greater demand for TMD simulations.

NC3A CCSD HLA Lab Integration Project

The Command and Control Systems Division has begun work in the development of a federation of division laboratories and testbeds based on HLA. During the next year it is anticipated that the TMD simulations integrated for CC02 will be expanded to include the C2 lab (ICC), and the electronic warfare (EW) and NATO Airborne Early Warning (NAEW) testbeds.

Semi-Automated Forces

The nature of the TBM threat lends itself to scripted simulation. Fire battery and infrastructure movements must be planned well in advance with launch and hide sites pre-surveyed to accommodate the large, cumbersome vehicles. Modern manoeuvre warfare as a general rule is dynamic and in order for the NC3A and the CAESAR project to support Article V high-intensity combat, an alternative to scripted scenario generation is required.

In November of 2001 the NC3A received the OneSAF simulation[7], a highly detailed code that contains automated behaviours based on military doctrine. The complexity of OneSAF requires multiple processors in order to support AGS operations; to this end a cluster PC has been assembled in the NACT to support battalion-level combat simulation.

The absence of TBM units in OneSAF has prompted the Agency to request JointSAF. This derivative of OneSAF has both TBM units as well as autonomous background traffic. Operating JointSAF would allow NC3A to achieve the next step in TMD training capability: linking dynamic simulated attack assets with the ICC Joint Targeting System, due for release in December 2002. JointSAF could also be a common link with the US Joint Forces Command (JFCOM) Joint Training and Simulation Center (JTASC), allowing greater participation in future simulation experiments.

Distributed Simulation

The logistics of transplanting the NACT equipment entail a substantial cost to the Branch; research into performing distributed simulation AGS experiments using the Combined Federated Battle Lab Network (CFBLNet) is under way. A network of high-capacity secure communications lines, CFBLNet may provide a more cost-effective way of conducting experiments. It is not used for operational applications.

Joint Distributed Engineering Plant (JDEP)

The Joint Distributed Engineering Plant concept was briefed to the NC3A in December 2001 and subsequent high-level discussions with US officials indicated that the NC3A is considered to be a candidate node on this advanced network. The CAESAR project also has voiced interest in distributed simulation as a means to provide additional program experiments at substantially lower cost.

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[7] Operational Testbed (OTB) International Release, version 1.0.

Synthetic Environment

Each of the AGS systems described here, be it a sensor simulation or an exploitation workstation, is a powerful geographic information system (GIS) that requires accurate and consistent data to operate and, perhaps more importantly, to interoperate. Digital mapping data is provided to the Agency through our SHAPE sponsor but given its purpose of supporting a single customer (the NATO command structure), interoperability is not an issue.

The coalition factor of AGS operations in the NACT requires that GIS data be provided too many systems some of which may not be compatible with the NATO GIS. An alternative is for the NACT to provide conversion to a common GIS standard.

The Open GIS Consortium (OGC) is currently under evaluation but an alternative is to employ the Synthetic Environment Data Repository Interchange Specification (SEDRIS), which has the advantage that it includes atmospheric information. Recently NATO Land Group 8 emphasized the value of SEDRIS (as well as HLA) as a means to achieve simulation interoperability.[8]

A drawback to the use of OneSAF/JointSAF is the difficulty and/or expense of creating terrain databases (compact terrain databases or ctdb). SEDRIS provides a capability to build ctdb files using SEDRIS Transmittal Format (STF).

SEDRIS associates (e.g. TNO, Northrop Grumman IT) have provided tools for processing the digital terrain elevation data (DTED) and vector map (VMAP) information necessary for simulating the robust land environment required for AGS. Work continues in this area and appears promising.

[8] Minutes from Mr. Gene Weihagen, Chair, NATO Land Group 8 on Training Simulation Interoperability, 31 January 2002.

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A Multiagent Based Model for Tactical Planning

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ABSTRACT

The classical paradigm in planning consists of making a precise plan taking into account the whole set of variables that may intervene in the project and under the supposition that none of the variables will change during the project development. In case there is an unexpected change the project manager will decide which action to carry out. He will base his decision on his own experience, since he will have less time to study the complete area of new possibilities. For these reasons it is vital to make a project plan as accurate as possible. Many times this objective is not easy to achieve, due to the different variables that intervene in the planning process.

From a general point of view the planning process is a combination of tasks, resources and objectives in order to achieve a goal. In the planning phase a project team must define the different tasks and how long each task will take; the resources that can be used in order to do the tasks and the goal or goals of the project.

This paper presents a multiagent based model that permits to develop two prototypes in different contexts. One of these prototypes was introduced in the NMSG symposium held in Breda (The Netherlands) in 2001. The conceptual model has been improved in order to be applied in another different context. A second prototype has been developed under the same conceptual model and using similar Artificial Intelligence Tools.

We use four different stimulus/response agents in order to solve specific functions, such as classifying, quantifying, assigning and finally optimising the response of the computer.

The first prototype is able to solve an artillery preparation or counter-preparation plan by using as few artillery units as possible. The second prototype solves the planning process in project management.

Usually, the way in which the project manager assigns the resources to the tasks determines the cost or the total duration of the plan. In simple projects, a person with specific experiences can build a plan but when there are many available possibilities to perform this assigning process, the combinatorial explosion exceeds the human capacity. On the other hand, when applying resources to tasks it is necessary to take into account the experience and knowledge of each human resource. These characteristics are normally defined with linguistic tags instead of using quantified values.

In this paper we present a solution that opens the door of a new paradigm that we call 'planning with control in real time'. A computer aided plan would support the project manager by proposing a faster and probably better solution than the human calculated option.

Keywords*: Planning, Task, Resources, Goals, Agents, Neural networks, Intelligent searches, Fuzzy logic, Heuristic algorithms.*

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

OVERVIEW

In projects management it is vital to make a project plan as accurate as possible. Many times this objective is not easy to achieve due to the different variables that intervene in the planning process. The classical paradigm in planning consists of making a precise plan taking into account the whole set of variables that may intervene in the project and under the supposition that none of the variables will change during the project development. In case there is an unexpected change the project manager will decide which action to carry out. He will base his decision on his own experience, since he will have less time to study the whole area of new possibilities.

In a very high percentage of cases, human personnel carry out manually the procedures used for tactical or strategic planning. These two different point of view have a different perspective of the planning process. We call tactical or short time planning when our scope is within a short term. We will work with tasks to be developed and the available resources for the plan. On the other hand, we talk about strategic planning when we think in a longer period of time. We focus our attention in the future and we try to make a long term plan by analysing facts or events.

From a general point of view the planning process in tactical environment is a combinations of tasks, resources and objectives in order to achieve a goal. In the planning phase a project team must define the different tasks and how long each task will take, the resources that can be used in order to do the tasks and the goal or goals of the project.

Nowadays, the necessity to make plans by analysing possibilities it's a fact. However it should always be supported by the capability of reorganization in real time if an unexpected factor modifies our previous plan. This new point of view concerning planning is what we are going to call 'Planning with computer aided control.'

Usually, the way in which the project manager assigns the resources to the tasks determines the cost or the total duration of the plan. In simple projects, a person with specific experiences can build a plan but when there are many available possibilities to do this assigning process, the combinatorial explosion exceeds the human capacity.

In this paper we present a solution that opens the door of a new paradigm such as 'planning with control in real time'. The model that we have developed is based on stimulus/response agents. Two prototypes have been built in order to be solved in different planning contexts by using the conceptual model. A computer aided plan would support the project or operation manager by proposing a faster and probably better solution than the human calculated option.

The aim of this paper is to present the result of the research about the mechanization of the reasoning process in the tactical planning process. The conceptual model is built on base of the Agents theory. To implement the different agents we have used Artificial Intelligence techniques such as neural networks, fuzzy logic, and intelligent searches assisted by heuristics algorithms.

As a future project, and within the same investigation line, we are creating a new conceptual model which will serve the base for the construction of new prototypes to resolve planning problems but this time within the strategic environment.

PLANNING CONCEPTS

If we look up the meaning of Planning in a dictionary we can find simple concepts such as 'act of arrangement for doing tasks by using some resources', 'make preparations', or 'to consider how to conduct actions in detail and arrange it in advance.'

Taking into account the purpose of our plan we can distinguish two different concepts. On one hand, we call tactical or short time planning when our scope is within a short term. We will work with tasks to be developed and the available resources for the plan. On the other hand, we talk about strategic planning when we think in a longer period of time. We focus our attention in the future and we try to make a long term plan by analysing facts or events.

TACTICAL PLANNING

Tactical planning is normally related to our daily activity and we look for a concrete purpose usually in terms of cost, time, effectiveness, etc. Projects management, whatever the field we deal with, is a good example of tactical planning.

From a general point of view, the success of a project depends on four different factors:

- Obtaining, elaborating and transmitting information
- Tactical planning, for a short period
- Logistics preparation by accumulating the necessary resources
- Accurate execution of the plan

The tactical planning process is a combination of tasks, resources and objectives in order to achieve a goal. In the planning phase a project team must define the different tasks and how long each task will take; the resources that can be used in order to do the tasks and the goal or goals of the project.

In case there is an unexpected change the project manager will decide which action to carry out. He will base his decision on his own experience, since he will have less time to study the complete area of new possibilities. For these reasons it is vital to make a project plan as accurate as possible.

This paper focuses its attention on the planning factor with the goal of reducing the time used in making it. To solve the planning problem we suppose that we have initially obtained the available information.

It's vital that we don't forget that even though we improve our way of making plans by following the planning models presented in this paper, we won't succeed if any of the other factors fail. A lack of coordination in logistic or an inaccurate execution would prevent carrying out the plan successfully.

Within the general planning system, we can observe some limitations that avoid assuring the project's complete success, due to the following factors:

- A long time is spent to make a plan, especially if the process is manual.
- The methods used in planning are complex, and they are sometimes applied under subjective criteria.
- The available time to make a plan is often short. This circumstance can imply a non debugged elaboration of the plan.
- The optimization of the plan is light or simply doesn't exist. Due to the scarce available time, it is considered that the plan is well done if it follows the rules that have been pre-defined.

STRATEGIC PLANNING

The concept of Strategic planning evokes a higher concept. Strategic planning is normally related to a far future and consists of studying past and present events in order to extrapolate the future. Statistical studies of Tendencies and Prospective (Godet [5]) are techniques used in economics, industry, sociology or politics in order to obtain a strategic plan.

During our every day live there are plenty of events, from domestic economy, standard of living, incidence of criminality, social integration, to radical terrorist attacks. All these events belong to a specific scenario in which we live.

The object of the strategic planning consists of analysing the events that have a direct incidence over the complete scenario. For example, the dramatic scenario lived on Sept. 11th 2.001 was the result of a determined number of events.

After studying the events that are linked to the scenario, a human expert group has to investigate the influence each event has over other events. This will enable a more in-depth study in terms of probabilities. The Delphi method (Dalkey [6]) is used to take the group to a common response. Since, we are talking about conditional probabilities the Bayes theorem has to be taken into account and the isolated probabilities for each event have to be adjusted. After fitting probabilities the analysts have to yield a set of scenarios with their consequent probability. This, taking into account that adding the probability of all possible scenarios is equal to 100%. Those scenarios with higher probability will be chosen for a sensitive analysis in detail.

We can follow a similar process to analyse different areas, such as banking, commerce, etc.

TOOLS: STIMULUS/RESPONSE AGENTS

An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors. An agent's behavior depends only on its percept sequence to date, then we can describe any particular agent by making a table of the action it takes in response to each possible percept sequence.

Before we design an agent program, we must have a pretty good idea of the possible percepts actions, what goals our performance measure that the agent is supposed to achieve, and what sort of environment it will operate in.

From a conceptual point of view, the tactical planning model can be built on the base of four agents: one in charge of the quantification, other for the classification process, other responsible for the assigning, and finally an agent in charge of making the Assigner Agent more efficient. Each of these four agents is based on a specific AI technique; in our case the quantifier/classifier agent is built on neuro-fuzzy techniques (Zadeh [7]) and the assigner/optimiser agent has been built by means of intelligent search algorithms.

CONCEPTUAL MODEL FOR TACTICAL PLANNING

Figure 1 describes the data transmission among agents. The Quantifier Agent is in charge of the quantification of some resources' characteristics; after this action the computer obtains a factor that will modify the tasks duration. Depending on the context we are planning on, it is possible the necessity of a classification, so we have arranged an Agent in charge of this process. The Assigner Agent is in charge of assigning the resources to the tasks, looking for the solution that fits the goal previously defined. The Optimiser Agent will shorten the searching time in case we need to make the Assigner Agent more efficient.

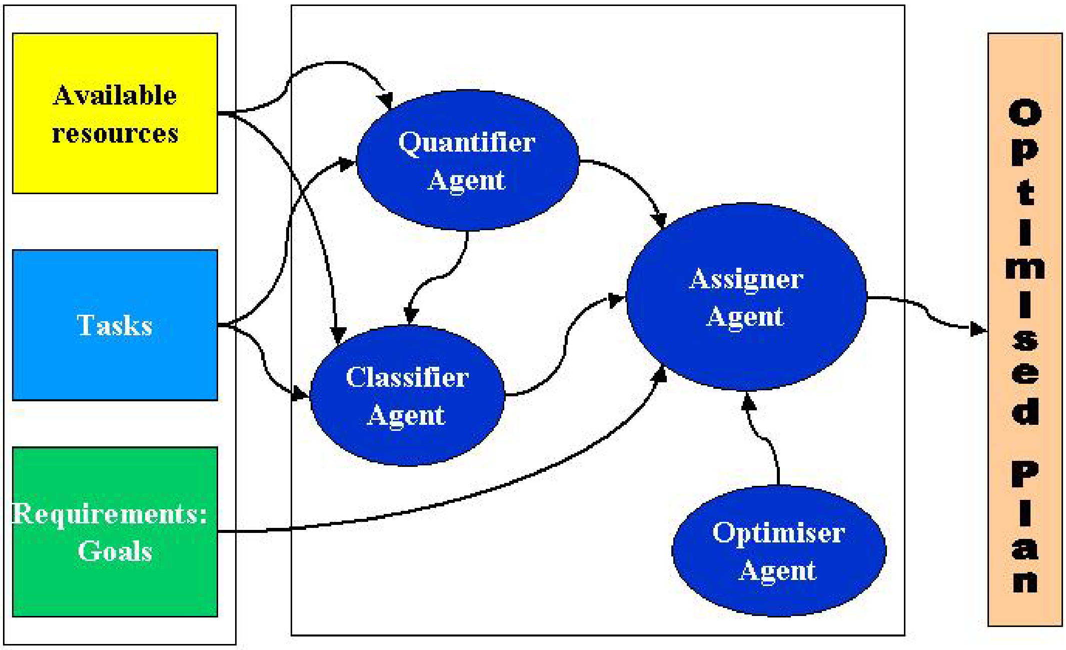


Figure 1: Tactical Planning Model.

The basic elements of each agent are shown in the following table:

Agent Type	Perceptions	Actions	Goals	Environment
Quantifier	A list of resources	Detecting resources characteristics	Reckoning a factor to modify task duration	A file stored in a hard disk, or a table in memory
Classifier	A list of resources	Detecting resources characteristics	A classified task or resource list	A file stored in a hard disk, or a table in memory
Assigner	A list of task and possible resources to be applied	Detecting plan's goals, applying search operators	An optimised plan	Files stored in a hard disk, or tables in memory
Optimiser	Variables within the assigning process	Use of an efficient search algorithm	An efficient and optimised plan	Code stored in a file or tables in memory

From a user's point of view the computerized planning system works as a black box, to which it's necessary to give input and it will yield a possible solution to the problem.

In our case, the input will contain information about three different aspects:

- Tasks to carry out in the project
- Available resources for the project and their profile to perform a specific task
- Requirements to build the plan: Goals

On the other hand, the system will give us an output, which will consist of a depurated plan.

In order to check the suitability of the conceptual model we have developed two prototypes that are involved in different environments. The first one deals with the Field Artillery planning and the second one tries to give a more accurate solution to the planning process in Project Management.

PROTOTYPE 1: FIELD ARTILLERY PLANNING

The aim of this prototype is to demonstrate the suitability of the mechanization of the reasoning process in field Artillery planning by using Artificial Intelligence (AI) procedures.

The research is focused in particular on the preparation and counterpreparation artillery plans, due to their special complexity. The rest of the different artillery plans could be solved by using similar tools, perhaps in an easier way.

In this kind of problems the combinatorial explosion is the factor that prevents man to prospect the whole possibilities set in real time. He only can obtain a possible solution without being certain that it is the best. For that reason, the Artificial Intelligent procedures and their implementation in high-performance computers are suitable to serve as a powerful tool in the planning process.

To serve as an example, we can imagine an artillery preparation plan for neutralizing twenty targets with five field artillery units in a ten-minute plan. The officer in charge of the planning process will take about thirty minutes to find a viable solution, which will not be optimised by respecting a minimum use of resources, and will not be free of possible human error. By using the computer aided planning tool, the computer explores nearly a hundred and thirty five thousand possible assignation states, and it yields the solution that best fits the porpoise of the plan by saving as many artillery units as possible and taking only a few seconds.

The analysis and results of this prototype are treated in deep in the paper entitled “A tactical planning approach by using AI. procedures” presented in the NMSG Symposium held in Breda (Nov. 2.001), J.M. Castillo, F. Arriaga [8].

PROTOTYPE 2: PROJECT MANAGEMENT

The goal of this prototype consists of the mechanization of the reasoning process in the planning phase of the project management by using AI procedures.

The research is focused in particular on computer science projects. It would be applicable to such projects with similar characteristics, especially those which represent the same response in task duration when applying several resources.

As well as in the Field Artillery planning prototype, the combinatorial explosion is the factor that prevents man to prospect the entire set of possibilities in real time.

The conceptual model we have elaborated on is built on the base of the Agents theory. To implement the different agents we have used Artificial Intelligence techniques such as fuzzy logic, neural networks and intelligent searches assisted by heuristics. First we use the fuzzy logic to quantify some linguistic tags which determine characteristics of the project resources; then a multilayer perceptron is used as a defuzzyfier. Once tasks and resources have been treated adequately, we implement an intelligent search algorithm to make the assignation process by looking for the goal defined previously.

FUZZY LOGIC: LINGUISTIC TAGS AND MEMBERSHIP FUNCTIONS

With the analysis of resources' attributes, we try to simplify the subjectivity of the human reasoning process. We define three distinctive characteristics when describing a specific resource:

- general experience in developing projects,
- capability to be applied on a specific task, and
- ability to carry out the task.

We have used three linguistic tags to define the human resource experience: *Novel*, *Junior* and *Senior*. The capability is defined by declaring the task or tasks on which the resource might be applied. Concerning the ability, which is related to the specific knowledge to solve a task in particular, we define four different degrees by means of four linguistic tags: *Scarce*, *Acceptable*, *Good* and *Excellent*. This information has to be provided by an expert human team.

We have to map the characteristics of experience and knowledge with the output which describes the efficiency in developing the task. We have given three degrees of efficiency: *High*, *Medium* and *Low*. We have applied a membership function to define every tag. The logical AND operator is used when applying the conditional rules. As a result we obtain an output pattern based on the Sugeno model (Sugeno [9]).

Figure 2 shows the twelve logic rules used to describe the possible conditional statements made by degrees of *experience*, *knowledge* and *efficiency*.

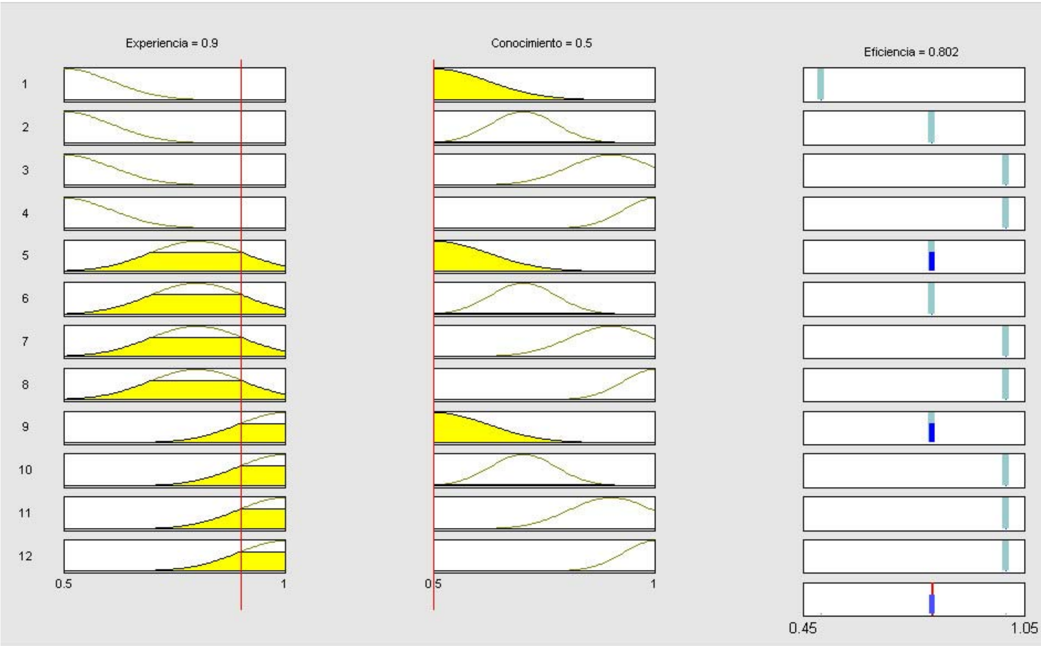


Figure 2: Conditional Rules.

DEFUZZY PHASE

In order to obtain a final factor in an easier computational way, we have implemented a neural network that has been trained with the input and output pattern. After the training phase we have validated the neural-fuzzy system with different patterns from the original training set.

The output of the neural-fuzzy system is a factor that describes the efficiency to carry out a specific task. This factor will affect directly the initial estimated duration of a task when applying the resource.

GOALS TO ACHIEVE IN PROJECT MANAGEMENT

One important input in the project planning model gives the rules on which the Assigner agent will base its search. The project manager will define which goal he wants to achieve, this goal has a direct influence when applying operators on behalf of the Assigner agent.

Initially we have preset three different goals that can be selected:

- Minimum use of resources and minimum cost of the project
- To carry out all tasks in a minimum time
- To finish the project in a limited time and with minimum cost

THE RESOURCES ASSIGNER AGENT

Once we have obtained a list of task and resources, our second goal is to solve the distribution problem. This problem consists of the correct selection of an available resource to be applied to a task. However, not all possible assignments fit the defined goal for the plan. This problem is solved by the Assigner agent, which is based on an Artificial Intelligence procedure, such as the intelligent search.

Due to the need of getting an optimized plan that matches a predefined goal, and the need of obtaining the plan in real time, we have implemented a heuristic algorithm that shortens the intelligent search process.

The variables that will intervene directly in the operator selection process within the search algorithm will be:

Available Resources

- Number of resources per type
- Resource’s experience in projects
- Resource’s knowledge in solving a specific task
- Resource’s cost per hour

Tasks To Do

- Tasks to develop within the project
- Duration of the tasks in days
- Dependencies between tasks
- Specific starting day for a task

In order to get a plan that fits the pre-defined goal, we have to take into account the remaining factors as variables within the production rules in our software code. These variables are:

- Number of work hours per day
- Goals:
  - Minimum use of resources and minimum cost of the project
  - To carry out all tasks in a minimum time
  - To finish the project in a limited time and with minimum cost

SEARCH OPERATORS

The resource operator is in charge of making all possible combinations, from a single resource to the whole set of possible assignments. On the other hand the task operator will yield a new state in the project plan by calculating all possibilities in starting a new task.

Depending on the goal, the search key consists of starting with a minimum of resources combining the tasks set; if no solution is reached we increase with a single new resource; and so on, until obtaining a plan that fits the pre-defined goal.

If the exhaustive search arrives to the last state by using all resources and the possible tasks combinations and no solution is found, the possibilities are either to increase the number of available resources or to reduce the task list.

The complexity of the exhaustive searches lies in the very high number of states produced in the seeking process.

In Figure 3 the operator's application on the set of states is shown.

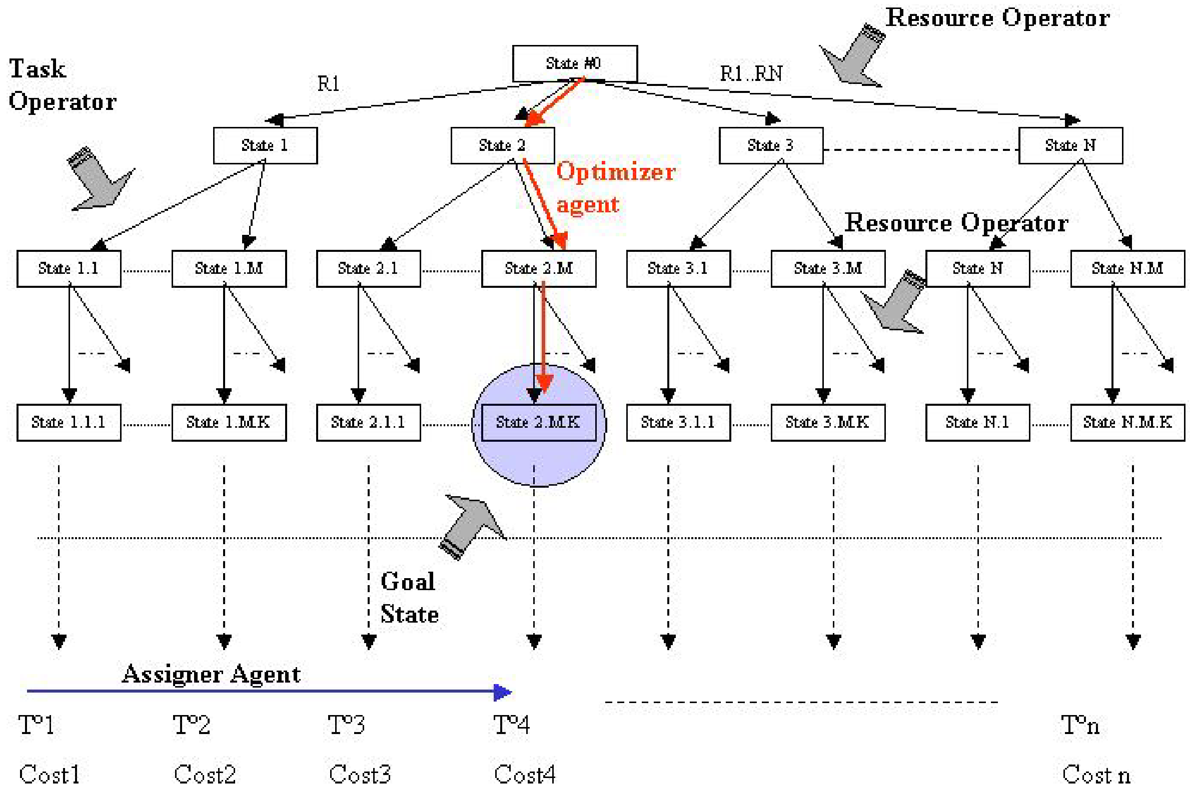


Figure 3: Heuristic Algorithm Application.

Only in case we have selected a project plan goal with the use of minimum time, we apply a heuristic algorithm, which will shorten the search process.

Our heuristic algorithm will establish what is the critical path of the project plan in every new state; and it will act by adding more resources in each task that belongs to the mentioned critical path in order to shorten the complete duration of the project.

PROJECT MANAGEMENT SOFTWARE

A software prototype has been developed to demonstrate the usability and suitability of the model. It has been built with very simple interfaces, that allows user introducing data and obtaining results in a pretty easy way.

We can summarize the use of the prototype in four steps: Introduction of tasks, definitions of resources' characteristics, definition of the project's goal and activation of the agents.

The results obtained from the use of the prototype permits assurance for the suitability of the model compared to other classical paradigms such as CPM (Critical Path Method).

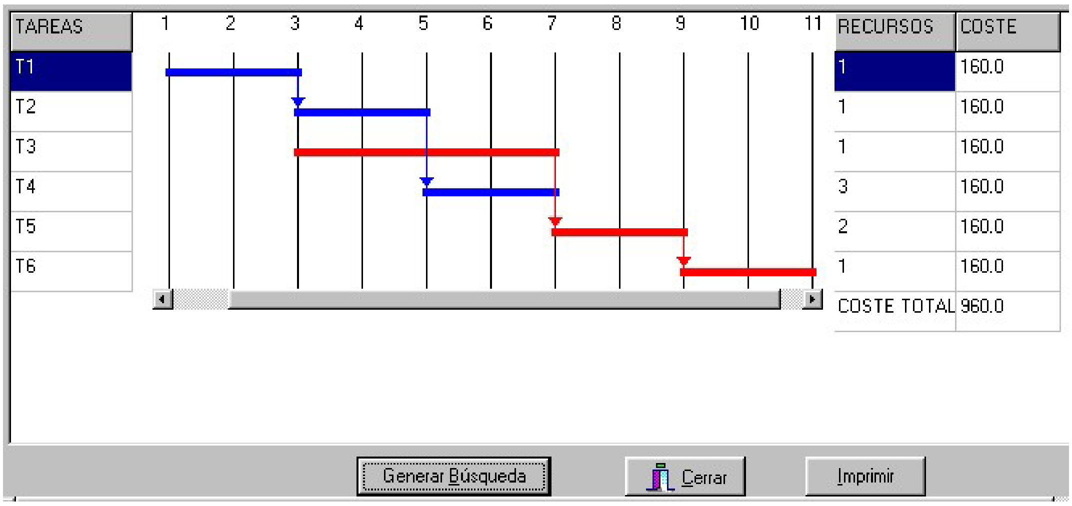
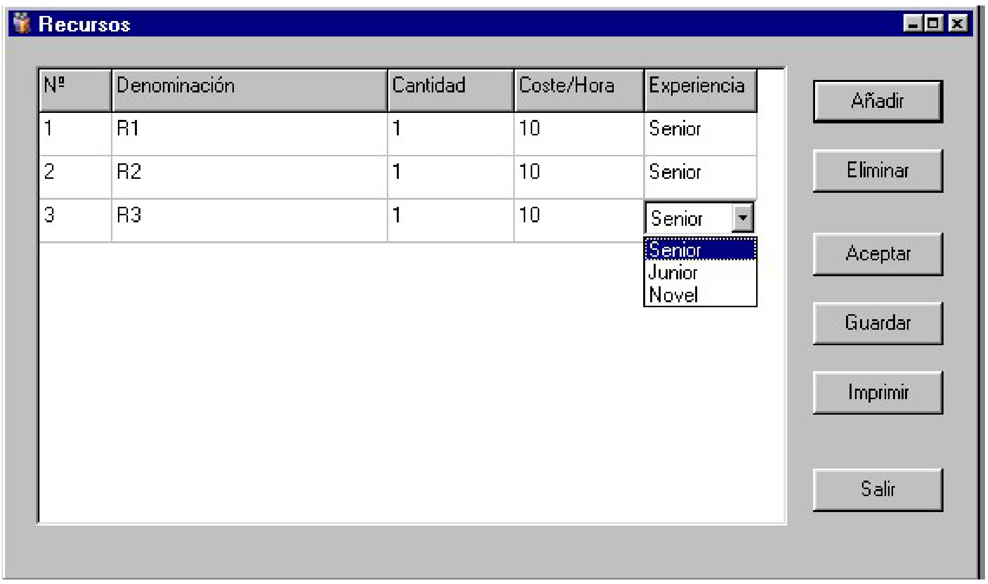


Figure 4: Project Plan.

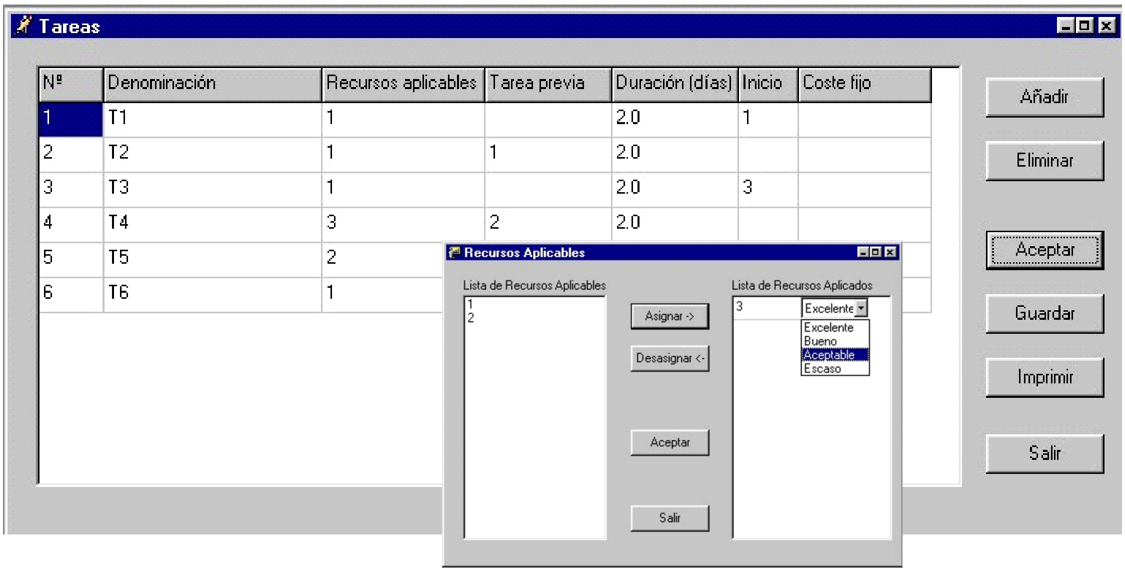
Example of Use

To use the software prototype it is necessary to accomplish four steps:

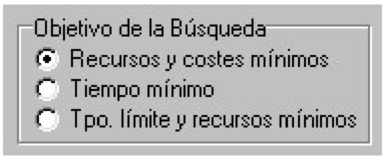
1) To generate/load the resources list



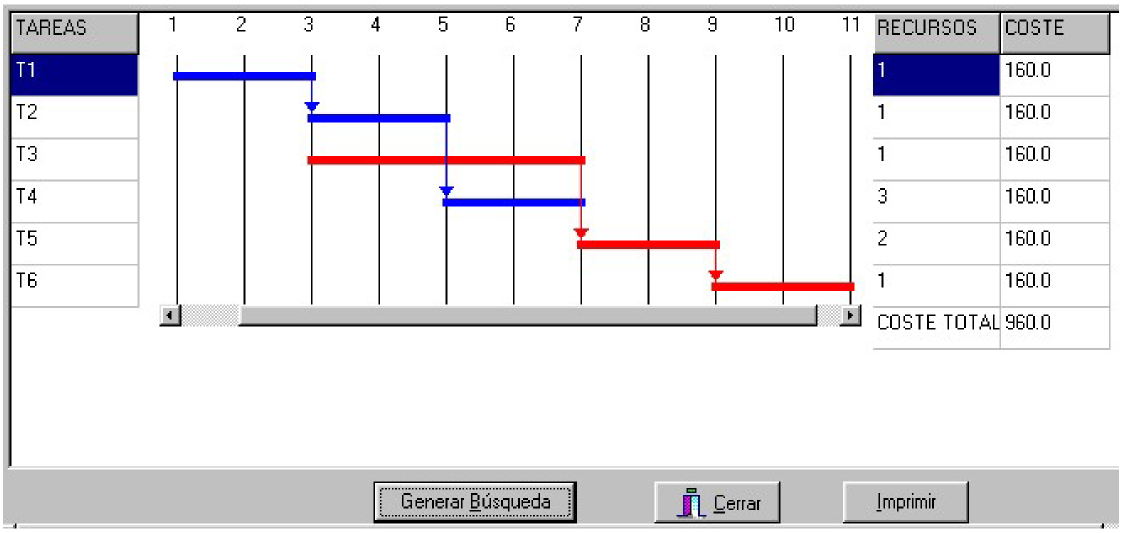
2) To generate/load a tasks list



3) To define the goal



4) To search the solution



Developing the Project

One of the most important advantages that this work can offer is having a plan with computer aided control. This characteristic implies the automatic reorganisation in real time if the scenario changes unexpectedly while the project is being developed. Therefore, we can obtain in a few milliseconds a new plan that fits the requirements of the new project scenario.

CONCLUSIONS

This paper presents a conceptual model for tactical planning. Under the same conceptual model we have built two prototypes in different contexts: Field Artillery Planning and Project Management. The model have been built on the base of Artificial Intelligence techniques.

The advantages and development of the Field Artillery Planning prototype are described in detail in the proceedings of the NMSG symposium held in Breda (Nov. 2001).

Regarding the Project Management Prototype, it introduces some advantages compared to the CPM and classical planning methods. This prototype improves the planning model approach of Castillo [10], by using a new agent responsible for the quantification of some linguistic patterns. The general advantages that this work presents can be summarized as follows:

- Capacity to manage the suitability of resources in terms of experience and knowledge and their influence in making a specific task.
- Declaration of the aim of the project in terms of time, resources or cost.
- Exhaustive search to get the best solution that fits the aim of the project.
- Capacity of reorganization of the plan in the execution phase of the project.

FUTURE PROJECT

After the results obtained in the field of Tactical planning, we are working on building a conceptual model to support Strategic planning. We expect to use successfully a neuro-fuzzy network in charge of reproducing the human knowledge and experience in making up a scenario by studying the influence among events. By using this procedures, we would talk about possibilities instead of probabilities and we will avoid using complex probabilistic techniques rather unclear for the human expert group in most cases.

Other problem that we are working on consists of determining which events we can influence on, in order to obtain a desired scenario. We are trying to implement an intelligent search to make the sensitive analysis of variables (in this case events) that can help us to get an ideal scenario.

In a similar way that for the tactical planning model, we have planned to develop a software prototype to demonstrate the suitability of the model and agents designed to perform a strategic plan.

If we obtain some results from the use of the strategic planning prototype we could offer other alternative to classical paradigms like the Prospective method.

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ITCS : l'infrastructure technique commune dédiée à la simulation pour l'acquisition

(ITCS: the Technical M&S Infrastructure for Supporting the SBA Process)

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RESUME

La DGA s'est engagée ces dernières années dans une démarche de simulation pour l'acquisition. Celle-ci passe entre autres par des processus nouveaux à définir, des standards à appliquer et des outils à déployer. Cet article balaie chacun de ces points, vus au travers du prisme de l'infrastructure technique commune de simulation (ITCS), qui fédérera l'ensemble des outils nécessaires à cette démarche. Cette ITCS est actuellement en cours de définition et sera déployée à moyen terme. Son objectif principal est d'une part de développer l'interopérabilité des simulations existantes et futures de la DGA, utilisées pour les diverses phases du cycle de vie des programmes, d'autre part de capitaliser ces simulations pour permettre leur réutilisation entre les phases d'un programme et entre les différents programmes.

Dans cet article, nous présentons les principaux jalons du projet et nous le positionnons par rapport aux autres initiatives OTAN ou européennes, dont les thématiques sont très proches : tout d'abord, la maquette d'une banque de données et de modèles développée dans le cadre européen EUCLID par quasiment tous les partenaires étatiques et industriels européens, ensuite la bibliothèque des ressources de la simulation, dont l'idée est proposée au sein du NMSG.

ABSTRACT

The DGA (General Directorate for Armaments) has been actively involved in simulation-based acquisition these past years. This needs defining new processes, applying standards and developing adequate tools. This paper addresses the latter: we will present the Joint Technical Simulation Architecture

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(ITCS, in French), which is currently specified and should be deployed shortly. Its main objective is on the one hand to federate the various simulations currently in use within the DGA for the various phases of the lifecycle of a program. On the other hand, capitalisation and configuration management processes of the data and models for SBA will be included in the ITCS.

In this article, we will present the keystones of the project and we will compare it with other initiatives which it will have to be interfaced with: first, the data and model repository developed under an EUCLID contract by most European governmental and industrial partners; second the simulation resource library studied by the NMSG.

1.0 INTRODUCTION

La complexité des systèmes de nos jours s'accroît dans tous les domaines, y compris dans la défense, à tel point que nous parlons plutôt de systèmes de systèmes aujourd'hui. La modélisation et la simulation (M&S) deviennent alors une discipline à part entière. En effet, les techniques et les outils de M&S apportent une aide précieuse aux processus d'ingénierie des systèmes tels que décrits par les normes EIA 632 ou IEEE 15288 (en préparation).

Ainsi, l'émergence et l'évolution de l'ingénierie des systèmes complexes se sont concrétisées en Europe par la création en 1998 de l'association française d'ingénierie système (AFIS) sous le patronage de l'*International Council on Systems Engineering* (INCOSE) et la création d'un nouveau pôle technique « conception des systèmes complexes » à la *Defence Evaluation and Research Agency* (DERA) en Grande Bretagne. En France, un nouveau domaine technique s'est également formé par la création en 1998 du département « Ingénierie des Systèmes Complexes » (SC) dans la Direction des Systèmes de forces et de la Prospective (DSP) au sein de la Délégation Générale pour l'Armement (DGA).

Parallèlement à cette mouvance, le *Defense Systems Management College* (DSMC) du *Department of Defense* (DoD) américain a introduit en 1998 la notion de *Simulation Based Acquisition* (SBA) [4]. Il s'agit d'un processus, basé sur l'utilisation de moyens de M&S durant tout le cycle de vie de l'acquisition d'un systèmes d'armes, permettant d'optimiser les performances des systèmes, les délais de réalisation et les coûts tout en maîtrisant les risques. Le concept sera repris sous le nom de *Synthetic Environment Based Acquisition* (SEBA) en Grande Bretagne et Simulation pour l'Acquisition (SA) en France.

La démarche de SA est engagée par la DGA depuis 3 ans. Les orientations stratégiques du domaine technique « Ingénierie des Systèmes Complexes » sont définies par le département SC dans sa politique technique et sectorielle. Ces orientations prévoyaient notamment la mise en place d'une équipe dédiée à la simulation pour l'acquisition à la DCE (Direction des centres d'expertise et d'essais): l'EPSA (équipe de projet simulation pour l'acquisition). Cette équipe, en place depuis septembre 2001, est en charge de l'outillage du processus SA, en particulier au travers de la définition et la mise en place d'une infrastructure commune de simulation à la DGA. Tous ces acteurs (SC, EPSA, centres de la DCE, CAD) contribuent à la maîtrise par la DGA de la complexité croissante des systèmes de défense, et s'attachent activement à mettre à disposition des équipes de programmes les outils de M&S qui leur permettront de :

- préparer les choix en matière de systèmes de défense, définir et évaluer l'architecture globale des systèmes de systèmes ;
- spécifier et valider les systèmes d'armes ou les systèmes d'information opérationnels ;
- assurer la cohérence technique tout au long du cycle de vie d'un système et en particulier garantir l'interopérabilité avec les autres systèmes ;
- promouvoir le savoir-faire et les produits de l'industrie de défense français à l'export.

Les architectes de la DGA (architecte technique de système, architectes de systèmes de force) doivent en disposer afin de réaliser les activités d'ingénierie des systèmes dont ils ont la responsabilité. Plus généralement, ces outils doivent pouvoir être partagés entre les différents intervenants (états majors, DGA, industrie) d'un projet (par exemple au sein d'une équipe de projet intégrée dans le cadre d'un fonctionnement en plateau).

Sur le plan technique, la maîtrise de l'outil de modélisation et de simulation nécessite :

- de savoir modéliser et simuler les grands systèmes complexes du futur (constitués d'un grand nombre d'éléments hétérogènes en interaction et répartis géographiquement) de manière adéquate ;
- de définir les méthodes et les outils permettant de partager, de capitaliser et de réutiliser les modèles ;
- de définir les règles et les standards pour assurer l'interopérabilité entre les outils de simulation développés dans les différents programmes.

Pour répondre à ces besoins, une étude a donc été lancée par le département SC dans le cadre du Programme d'Étude Amont (PEA) ARchitecture COmmune de SIMulation (ARCOSIM) volet SA en 2001. L'objectif attendu est décrit dans la section suivante. Les divers thèmes abordés par cette étude sont présentés dans la section 3. Comme d'autres projets nationaux ou en coopération traitent des problématiques similaires à l'étude ARCOSIM-SA, nous les mettrons en relation dans la section 4. La section 5 présente la réalisation de l'étude proprement dite, à savoir l'état des lieux, les travaux en cours et le planning prévisionnel du déploiement de l'ITCS. Et enfin, nous conclurons en présentant les travaux futurs, les efforts complémentaires ainsi que les bénéfices déjà observés.

2.0 OBJECTIF GLOBAL

L'étude ARCOSIM-SA est pilotée par le Centre Technique d'Arcueil (CTA) où se trouve l'EPSA. Les autres centres d'expertise et d'essais sont impliqués dans cette étude en plus du Centre d'Analyse de la Défense. Elle consiste à spécifier une Infrastructure Technique Commune de Simulation (ITCS) permettant de fédérer l'ensemble des outils existants de M&S de la DGA et des milieux industriels ou de recherche (i.e. ONERA, CEA).

Cette ITCS devra permettre, à terme, d'assurer l'interopérabilité, la capitalisation et la réutilisation des modèles et des simulations au sein de ces communautés de M&S. Elle devra prendre en compte différents types de simulation : simulation constructive (temps réel ou non), simulation instrumentée, simulation pilotée, simulation hybride (respectivement *constructive*, *live*, *virtual* ou *« Man in the loop » et « Hardware in the loop » simulation* en anglais).

L'ITCS ne se limitera pas à un simple environnement informatique de M&S. Elle devra inclure des bases de connaissance ; des guides méthodologiques de spécification, de conception et de développement de modèles et de simulations ; des guides liés aux processus de Vérification, Validation et d'Accréditation (VV&A) ; des guides sur l'utilisation des standards de M&S (i.e. HLA, SEDRIS, etc., cf. § 3.3) ; des recommandations sur les clauses contractuelles d'achat des outils M&S. Nous verrons en détail ces différents aspects plus loin dans les sections 3 et 6.

Il est certain que les experts métiers et les développeur d'outils M&S seront les opérateurs de première ligne sur l'ITCS mais il est important de souligner que l'ITCS devra aussi fournir à terme des outils simples aux architectes de la DGA et aux spécialistes des services de programmes pour les aider à spécifier et à concevoir les futurs systèmes d'armes de la France.

3.0 PERIMETRE DE L'ETUDE

À partir de l'objectif global, il est assez aisé de déterminer les briques de base qui doivent constituer l'ITCS. Nous allons les présenter en détail dans cette section. En même temps, nous dressons l'ensemble des problèmes soulevés par ces constituants que nous tâcherons de résoudre dans l'étude ARSOCIM-SA ou à l'aide des résultats issus d'autres études et projets.

Les simulations concernées sont celles allant du niveau des phénomènes physiques jusqu'au niveau tactique ainsi que les simulations technico-opérationnelles depuis le niveau système jusqu'au niveau opératif.

3.1 Bases de données

Les données liées au processus de simulation sont fort nombreuses. Nous les classons en trois types : les données caractérisant ce que l'on veut simuler (le scénario), les données liées aux outils utilisés pour cette simulation (les modèles), et les données produites par ces simulation (les résultats). Ces trois types de données doivent être capitalisés : chacun est en effet le fruit d'un processus d'élaboration parfois très long, et nécessitant la mobilisation d'experts. C'est notamment le cas des scenarii dont on néglige souvent la conservation, alors qu'ils sont fondamentaux lorsqu'on veut par exemple tester la non-régression d'un modèle.

Les bases de données associées ne sont pas juste des bibliothèques de modèles ou un ensemble de données brutes. Elles doivent aussi contenir toutes les informations (méta-données) utiles à l'utilisateur final pour que la réutilisation soit la plus efficace possible. En fait, chaque base de données est un *repository* au sens de la *Simulation Resource Library* que le groupe de travail OTAN MSG012-TG009 est en train de définir (voir paragraphe 4.2).

Une des difficultés liées aux données réside dans le fait que les informations à stocker ne sont pas structurées. Pour les modèles, l'on trouvera par exemple des documents décrivant le principe de modélisation, sous forme de texte ou d'un langage de modélisation type UML, le modèle implémenté, sous forme de codes sources, objet ou exécutable…

3.2 Services offerts

En plus des bases de données, un certain nombre de fonctionnalités communes aux simulations doivent être partagées au travers de l'ITCS. L'objectif est de factoriser ce qui peut l'être dans le processus de la simulation, afin de faciliter des processus transverses associés, tels que la gestion de configuration ou le VV&A (vérification, validation et qualification). Chacun des facteurs suivants fait l'objet d'études spécifiques menées dans des cadres nationaux ou internationaux (cadre contractuel européen EUCLID, groupes de recherche du NMSG, coopérations bilatérales).

Le premier facteur concerne les services de communication et d'accès. Si l'infrastructure matérielle entre les centres est en cours de mise en place dans le cadre du projet « Réseau d'entreprise DGA », l'ITCS devra toutefois définir des mécanismes communs d'accès à l'information, de protection de l'information, qu'ils soient techniques ou organisationnels. Par ailleurs, le choix de technologies particulières de communication au sein d'une simulation doit tenir compte ou faire évoluer les capacités du réseau mis en place.

Le second facteur est lié à la préparation des simulations : un éditeur de simulation doit permettre de définir le chaînage des modèles en fonction de la simulation souhaitée par l'utilisateur final. Une fonction d'édition de scenarii est également prévue. Une voie à l'étude s'inspire des développements présentés par Burns *et al.* dans [1] qui proposent un générateur de scenarii indépendant des plates-formes de simulation.

Le troisième service concerne la dynamique des simulations (activation et synchronisation des modèles) regroupées dans le concept de moteur de simulation.

Les outils d'affichage pour la visualisation ou d'analyse des données font également partie des services communs offerts par l'ITCS. L'utilisateur doit pouvoir choisir le type de d'affichage ou les applications d'analyse des données en fonction de son besoin. Lorsque les applications de M&S le permettent, il suffit d'utiliser les outils intégrés dans ces applications. Sinon, l'ITCS doit proposer à l'utilisateur des interfaces graphiques génériques ou des outils communs d'analyse des données. Ainsi, le problème de compatibilité des formats des données se pose, en plus du celui relatif au couplage des modèles. Nous rediscuterons de cet aspect au § 3.3.

Enfin, des interfaces utilisateur doivent permettre d'exécuter et de gérer les applications de simulations, ainsi que d'administrer l'ITCS dans son ensemble pour garantir la disponibilité des services offerts et assurer une cohérence d'ensemble.

3.3 Standards et normes

La présentation du paragraphe précédent soulève un certain nombre de problèmes à résoudre pour favoriser l'interopérabilité et la réutilisation des modèles, des simulations et des données. Il est donc nécessaire d'homogénéiser la représentation et les spécifications de ces objets ainsi que de leurs interfaces. Pour cela, différents standards et normes sont identifiés comme des solutions potentielles à nos problèmes.

En matière de représentation et de spécification des modèles et des simulations, l'utilisation de *Unified Modeling Languge* (UML) facilite leur réutilisation. Aussi, certains outils commerciaux proposent des suites de test permettant de vérifier et valider les spécifications. Ce langage possède donc des bons atouts pour être préconisé par l'EPSA, voire intégré dans l'ITCS.

Cependant, l'*Object Management Group* (OMG) promeut une nouvelle approche basée sur le *Model-Driven Architecture* (MDA) dans laquelle les modèles de l'*Object Management Architecture* (OMA) deviennent des méta-modèles qui sont génériques et indépendants des plates-formes. Ces méta-modèles sont encore appelés *Platform Independent Model* (PIM). Le département SC a lancé une étude sur ce concept afin de concevoir des PIM pour la modélisation et la simulation (voir étude COCA au § 4.1 pour plus de détails).

Un autre langage, *Simulation Reference Markup Language* (SRML), est également à prendre en considération dans notre étude. Il permet de décrire la structure et le comportement des modèles en *eXtensible Markup Language* (XML). Il favorise au même titre que l'UML à la réutilisation des modèles et des simulations. De plus, un article récent [6] soutient que ce langage peut servir à représenter les *Base Object Models* (BOMs) en prenant en compte les spécifications du standard *High Level Architecture* (HLA) pour assurer l'interopérabilité.

Quant à la représentation et à la spécification des données, le standard *Synthetic Environment Data Representation Interface Specification* (SEDRIS) promu par le DoD américain a été retenu. Ce standard contribue à l'interopérabilité entre les modèles et les simulations en unifiant la sémantique et le format des données. Comme ce standard n'est pas encore suffisamment mature pour être appliqué sans précaution aujourd'hui, nous suivons de près son évolution, et cherchons à le faire évoluer en fonction de nos retours d'expérience en cours.

Pour compléter l'interopérabilité entre les modèles et les simulations, il est aussi nécessaire d'avoir un formalisme rigoureux pour les échanges de données. Le langage XML offre cette possibilité. Celui-ci est largement utilisé dans les technologies Web. Utilisé par les bases de données de l'ITCS, il offre la possibilité d'importer et d'exporter des données vers d'autres bases de données.

Comme l'ITCS sera utilisée pour réaliser des simulations distribuées, le standard HLA est bien évidemment pris en compte dans notre étude. Des actions complémentaires sont engagées depuis plusieurs années pour évaluer quantitativement l'apport de ce standard (en étudiant également les deux versions 1.3 NG du DMSO et IEEE 1516, ainsi que les principaux RTI associés) et pour mettre en place une capacité de certification nationale. Nous envoyons le lecteur au paragraphe 4.1 pour une description plus détaillée de ces actions.

À moyen terme, l'ITCS devra intégrer les capacités d'essais des divers centres, et permettre de mettre en œuvre le cercle vertueux simulation-essais. Aucun choix définitif n'a été fait dans ce domaine, et la définition des exigences fonctionnelles n'est pas non plus arrêtée. Une veille active menée dans ce domaine a mis en évidence quelques solutions récentes : la *Test and Training ENabling Architecture* (TENA) doit être analysée et évaluée quant à son applicabilité à nos simulations. Les présentations effectuées au *Fall 2002 Simulation Interoperability Workshop* montrent que cette architecture est plutôt orientée vers les simulations d'entraînement. Mais elle semble présenter également des capacités intéressantes pour la communication entre installations d'essais et simulations, et permettrait donc de concrétiser la synergie essais-simulation. La pertinence de cette architecture pour nos simulations est donc à l'étude, en complément d'HLA, sans doute avec l'éclairage du projet *Joint Distributed Engineering Plant Technical Framework* [2], dont la philosophie est très proche de celle de l'ITCS.

Enfin, les protocoles de télécommunication tels que IPSec/IPv6, *Secured Hypertext Transfer Protocol* (HTTPS), *Single Object Access Protocole* (SOAP) sont également étudiés quant à leur adéquation aux besoins de l'ITCS. Il est très probable que l'on retienne ces protocoles si nous voulons nous interfacer facilement avec l'environnement synthétique de développement de simulations qui est en phase de conception dans le projet européen EUCLID RTP 11.13 (voir § 4.2 pour une description sommaire du projet et [3] pour une présentation détaillée), et que nous devons intégrer dans notre infrastructure, au vu de l'investissement financier réalisé dans ce projet de coopération.

3.4 Méthodes et processus

Dans le cadre de notre étude, il a été décidé de proposer des méthodes et de définir des processus permettant d'accompagner les utilisateurs finaux de l'ITCS dans leurs activités de M&S. L'inclusion de ces éléments dans le référentiel méthodologique des bénéficiaires et utilisateurs de l'ITCS est un élément clé de la réussite du projet. Ceci contribue en effet à rendre l'utilisation de l'ITCS optimale afin de répondre efficacement aux contraintes de performances, de délais et de coûts dans le développement des systèmes d'armes.

Compte tenu de la complexité des infrastructures techniques de simulation de nos jours, même si elles sont composées essentiellement de logiciels, il n'est pas absurde de les considérer comme des systèmes complexes, ou encore des systèmes de systèmes. Ainsi, des méthodes théoriques immédiatement applicables sont issues des normes d'ingénierie des systèmes telles que EIA 632 ou IEEE 15288. Or la mise en pratique de ces processus est souvent mal menée et lourde, c'est pourquoi la DGA participe à certains groupes de travail de l'AFIS (organisation nationale, dont la description détaillée et le programme de travail est consultable sur le site Internet suivant : http://www.afis.fr) tels que :

- architecture système ;
- méthodes et outils ;
- intégration, vérification, validation et qualification.

Ces groupes de travail sont constitués de participants venant des milieux industriels, universitaires et étatiques. L'objectif commun consiste à établir des bonnes pratiques, des proposer des outils et d'échanger les retour d'expérience de chacun.

D'autres processus tels que le *FEderation DEvelopment Process* (FEDEP) ou le *Synthetic Environment DEvelopment Process* (SEDEP), inspirés par l'ingénierie des systèmes mais orientés M&S, sont également pris en compte dans l'étude ARCOSIM-SA.

Un autre processus très important est celui de la Vérification, Validation et Accréditation (VV&A) des données, des modèles et des simulations. Il est clair qu'une fois que le processus de développement des produits de M&S est défini, l'application du schéma itératif de V&V au sens de l'ingénierie des systèmes (cf. article de J. Lake [5]), tout le long du cycle de vie de ce processus, constitue une étape incontournable si l'on veut un processus de VV&A réussi.

Ensuite, un deuxième niveau de V&V permettra de s'assurer que les produits de M&S développés sont « représentatifs de la réalité » (à un certain degré de granularité près) afin que l'accréditation puisse être prononcée. Ainsi, nous constatons que le processus VV&A implique la mise en place d'une organisation appropriée maîtrisant l'ensemble de ces processus. Cette tâche difficile fait l'objet d'une étude spécifique, dans le cadre du PEA REVVA (cf. § 0), qui ne démarrera qu'à la fin de l'année 2002. Le but commun consiste à favoriser l'interopérabilité et la réutilisation des produits de M&S.

4.0 PROJETS EN RELATION

Compte tenu des nombreux points durs soulevés par l'étude ARCOSIM-SA, un certain nombre de projets nationaux sont lancés pour rechercher des solutions appropriées. Par ailleurs, des initiatives complémentaires ou similaires à l'étude ARCOSIM-SA sont également à prendre en considération dans la conception de l'ITCS si nous souhaitons étendre son interopérabilité et sa réutilisation au-delà des simulations nationales. Nous présentons dans cette section les principaux projets nationaux et ceux en coopération qui concernent directement l'ITCS.

4.1 Projets nationaux

Plusieurs études amont concernent la simulation distribuée, en terme de performance et de sécurité d'information : PERFOSIM, ARCOSIM-HLA et RICOS.

L'étude PERFOSIM (PERFOrmance des SIMulations distribuées) a pour but d'évaluer *a priori* les performances d'une simulation distribuée existante ou future. Cette étude a pris fin en juillet 2002. Des outils de simulation de fédérations HLA développés dans le cadre de cette étude sont aujourd'hui disponibles, et alimentent la bibliothèque d'utilitaires de l'ITCS. Ils permettent ainsi aux architectes de simulations distribuées d'évaluer la performance de leur système de simulation avant même de l'avoir réalisé et ainsi d'en optimiser l'architecture.

L'étude ARCOSIM-HLA consiste d'une part à évaluer la complétude du standard HLA et des outils logiciels associés par rapport aux besoins de la simulation distribuée de défense, notamment en termes de performances, fonctionnalités et sécurité ; et d'autre part à mettre au point des méthodes de capitalisation et de réutilisation des modèles de données de simulation. Cette étude de 18 mois a démarré en juillet 2002. L'étude sur les performances comprend notamment l'évaluation de 6 RTI sur étagère dont celles du DMSO 1.3 NG, des sociétés Pitch (1.3 NG et IEEE 1516) et Mäk, de l'ONERA (CERTI). L'étude sur la sécurité concerne plus précisément la protection des informations relatives aux modèles et aux données d'une simulation par rapport aux autres fédérés (cas d'une fédération multinationale, ou d'une fédération simulant un système complexe et répartie entre plusieurs industriels concurrents).

La sécurité interne d'une fédération de simulation distribuée étant prise en compte par l'étude ARCOSIM-HLA, celle concernant l'infrastructure de réseau de simulation distribuée est traitée dans le PEA RICOS (Réseau d'InterCOnnexion de Simulations). L'objectif de cette étude, qui entre dans sa phase finale, consiste à développer la meilleure architecture possible pour un réseau sécurisé de simulation distribuée français, interconnectant des centres d'études des armées et de la DGA. Des expérimentations du standard HLA ont été menées sur ce prototype à l'aide de cas concrets. Le niveau minimum de sécurisation est confidentiel défense. Dans le cadre de cette étude, une méthodologie est également mise au point pour conduire les exercices interarmées de façon distribuée. Des résultats intermédiaires particulièrement intéressants ont déjà été obtenus dans cette étude qui doit s'achever aux alentours de juin 2003.

Avec la disponibilité des stations de travail de type PC (*Personal Computer*) puissantes et très bon marché, il est aujourd'hui envisageable de disposer, à moindre coût, des ressources de calculs haute performance par agrégation de PC au sein de clusters ou de grilles. Parallèlement, l'offre croissante des logiciels libres de qualité industrielle, notamment le système d'exploitation LINUX, permet d'avoir gratuitement (ou à très bas prix) des solutions de qualité que l'on peut maîtriser et même adapter grâce à la disponibilité du code source. Toutefois, l'implémentation de simulations haute performance sur ce type de plate-forme est ardue. Il manquait jusqu'ici un système capable de rendre transparente la distribution voire l'hétérogénéité du support matériel. C'est ce que propose le système d'exploitation distribué, GOBELINS, de l'IRISA (Institut de Recherche en Informatique et Systèmes Aléatoires) de Rennes, qui permet à l'utilisateur de « voir » un cluster de PC comme un ordinateur multiprocesseurs (SMP) unique. L'étude COLISSYMO (Cluster Opérationnel sous LInux pour la Simulation de SYstèmes et la MOdélisation) a pour but de tester une architecture de clusters et de développer des outils logiciels associés pour les simulations de défense. Le système d'exploitation LINUX modifié sera, à l'issue de l'étude, disponible au public sous forme de logiciel libre.

L'étude CAPSULE (Conception Abstraite Pour Simulation permettant la ré-Utilisation des modèLEs) a pour objectif de concevoir des modèles métiers indépendants des plates-formes de simulation. Pour cela, l'étude s'oriente vers l'approche MDA qui permet de développer des PIM pour les besoins de l'ITCS. La fin de ces deux études est programmée vers fin 2004.

En plus de ces aspects purement techniques, nous avons également lancé une étude méthodologique sur le processus VV&A, il s'agit du PEA REVVA (REférentiel pour la Vérification, Validation, Accréditation des données, modèles et simulations). La principale attente de ce PEA est l'élaboration d'un standard internationale permettant de partager les bonnes pratiques de VV&A au sein de la communauté M&S en France mais aussi chez nos partenaires européens. Ainsi, l'essentiel du PEA REVVA est pris en compte par le biais d'une coopération européenne EUCLID qui devrait démarrer à la fin de l'année 2002. Il est à souligner que cette étude sur le VV&A est un aboutissement des réflexions menées sur le sujet depuis plusieurs années, en particulier en coopération avec le Royaume-Uni.

4.2 Projets en coopération

Parmi les autres projets en coopération, deux d'entre eux méritent particulièrement d'être pris en compte dans l'étude ARCOSIM-SA : EUCLID RTP 11.13 « *Realising the Potential of Networked Simulation in Europe* » et NATO *Simulation Resource Library*.

La premier projet regroupe 13 pays et 23 entreprises européennes. Le Royaume-Uni est le pays pilote dans ce projet. L'objectif du projet est la mise au point de méthodes et outils pour la spécification, la conception et la mise en œuvre d'environnements synthétiques multinationaux. Dans ce cadre, un processus (SEDEP), dérivé du FEDEP américain, a notamment déjà été défini pour le développement d'environnements synthétiques. Pour chacune des étapes de ce processus, des outils *ad hoc* seront réalisés pour aider les différents acteurs dans leur travail, depuis la capture du besoin jusqu'à l'exploitation des résultats. Ce projet contribuera donc fortement à l'amélioration du processus de développement des simulations et de leur utilisation, que ce soit pour l'entraînement, la répétition de mission ou l'acquisition. Actuellement, le projet entre dans sa dernière année. Une architecture technique est déjà largement définie (voir l'article de K. Ford [3] pour plus de détails). Elle est prise en compte dans la définition l'ITCS, afin que cette dernière puisse éventuellement constituer la module français de cet environnement distribué d'aide à l'ingénierie et à la mise en œuvre des simulations, et partager les ressources communes de M&S.

Concernant ce dernier point, le *NATO Modelling and Simulation Group* (NMSG) s'intéresse aussi de près à la mise en place d'une base de données pour capitaliser et partager des ressources de M&S au sein des pays membres et des partenaires pour la paix de l'OTAN. Pour cela, un groupe de travail intitulé « *NATO Simulation Resource Library* » (*Task Group MSG012-TG009*) s'est constitué depuis fin 2001 pour spécifier les exigences communes de cette une base de données. Cinq pays participent aux travaux de ce groupe, ce sont dans l'ordre alphabétique : l'Allemagne, le Canada, la France, la Norvège et le Royaume-Uni. Les États-Unis y participe également en fournissant leur retour d'expérience et des documentations sur leur outil MSRR (*Modeling and Simulation Resource Repository*). Les besoins nationaux sont bien évidemment pris en compte mais tout en privilégiant une vision commune des caractéristiques de données et des ressources à capitaliser. Les travaux du projet EUCLID RTP 11.13 sur la capitalisation sont aussi analysés et discutés dans ce groupe de travail de façon à faciliter la réutilisation et l'interopérabilité de tous ces outils de capitalisation. Un rapport d'étude sera finalisé par ce groupe de travail dès début 2003. Il présentera la solution proposée, l'organisation à mettre en place et les efforts financiers requis.

5.0 ORGANISATION DE L'ETUDE

Après avoir dressé un panorama sur les problèmes généraux à traiter dans l'étude ARCOSIM-SA et les projets clefs qui le concernent, nous allons présenter la démarche retenue pour le développement de l'ITCS ainsi que le calendrier de déploiement de l'ITCS.

Compte tenu de la multitude et du degré d'avancement divers des études lancées par la DGA pour soutenir la démarche de simulation pour l'acquisition en France, il a été décidé de mener le développement du socle technique de cet élan de façon incrémentale. Une première version de l'ITCS ne prendra en compte que les services fondamentaux de la simulation distribuée. Dans les phases successives, les processus transverses tels que le VV&A seront instrumentés, le champ des simulations prises en compte par l'ITCS sera élargi, sa communication avec les installations d'essais sera précisée, et enfin, l'ouverture de l'ITCS sur des acteurs industriels et étrangers sera considéré.

Par ailleurs, la démarche retenue est participative. Elle repose sur une participation active des centres utilisant la simulation pour leurs activités. Cela garantit une prise en compte correcte de la difficulté que représentera pour les opérateurs de simulation la transition de leur outils historiques vers l'ITCS, et de la traiter de façon adéquate.

5.1 L'état des lieux

Le projet d'ITCS est structurant pour l'ensemble des acteurs français de la simulation pour l'acquisition. Mais il ne peut pas faire abstraction de tous les moyens existants aujourd'hui, ainsi que des compétences associées. Pour son lancement, il était donc fondamental d'impliquer une communauté large, mais surtout représentative de tous ces acteurs. Chacun des centres de la DCE a donc nommé un correspondant simulation, constituant ainsi le réseau d'expert nécessaire pour relayer l'élan « simulation pour l'acquisition » sur l'ensemble des sites. Cela a permis de fournir à chacun une vision globale et partagée du paysage M&S au sein des centres d'études de la DGA. Chacun a pu constater la diversité des outils mis en œuvre : diversité de technologie des outils, diversité de finalité, diversité de granularité des modèles, diversité de vocabulaire…

Ce point s'est avéré très positif pour la suite du projet, mais également pour les centres eux-mêmes : ayant fréquemment des problèmes analogues à résoudre, ils ont pu constater que des solutions existaient déjà sur d'autres sites. Des clubs utilisateurs se sont d'ailleurs organisés pour prolonger ces échanges initiaux fructueux.

En parallèle, de nombreuses interviews ont été organisées auprès des équipes de direction de programme, dans les domaines aéronautique (avions, drones et missiles), terrestre et maritime. Ces équipes sont les bénéficiaires immédiats des résultats de simulation : ceux-ci les aident dans leurs choix sur l'orientation à prendre pour les différents jalons du déroulement des programmes. Ces rencontres ont permis de prendre conscience des divers modes de fonctionnement, d'identifier les interlocuteurs privilégiés dans les équipes pour les activités M&S (« architectes système », responsables de marque, manager), et de découvrir enfin des pratiques assez variables sur ce domaine, qu'il s'agisse de la démarche retenue, des outils utilisés, des relations avec les industriels, ou des difficultés rencontrées… Toutes ces informations sont bien sûr prises en compte dans la définition de l'ITCS qui, en tant qu'outil essentiel de la conduite du changement, doit soutenir l'évolution vers l'application généralisée des principes de la simulation pour l'acquisition.

Enfin une analyse bibliographique des initiatives analogues à l'ITCS (notamment JDEP, JVB, JSB, VPG) lancées principalement par les États-Unis, nous permet de tirer profit de leur expérience dans ce domaine, et d'espérer pouvoir éviter certains écueils déjà connus.

5.2 L'analyse fonctionnelle de l'ITCS

Un des écueils majeurs pour les projets importants qui s'étalent sur plusieurs années, réside dans l'utilisation de technologies dont le cycle de maturité est bien plus court. C'est pourquoi il a dû être fait, autant que possible, abstraction des solutions techniques qui peuvent répondre aux besoins de l'ITCS.

L'exercice majeur est donc de définir précisément et exhaustivement les fonctions attendues de cette infrastructure, de caractériser ses utilisateurs, ses milieux environnants, et ce, pour la totalité de son cycle de vie, de son déploiement jusqu'à son maintien en condition opérationnelle. Cette analyse fonctionnelle se terminera à la fin de cette année.

Nous pouvons dores et déjà fournir une vision initiale de l'architecture fonctionnelle de l'ITCS. Cette vision est représentée sur le schéma Figure 1.

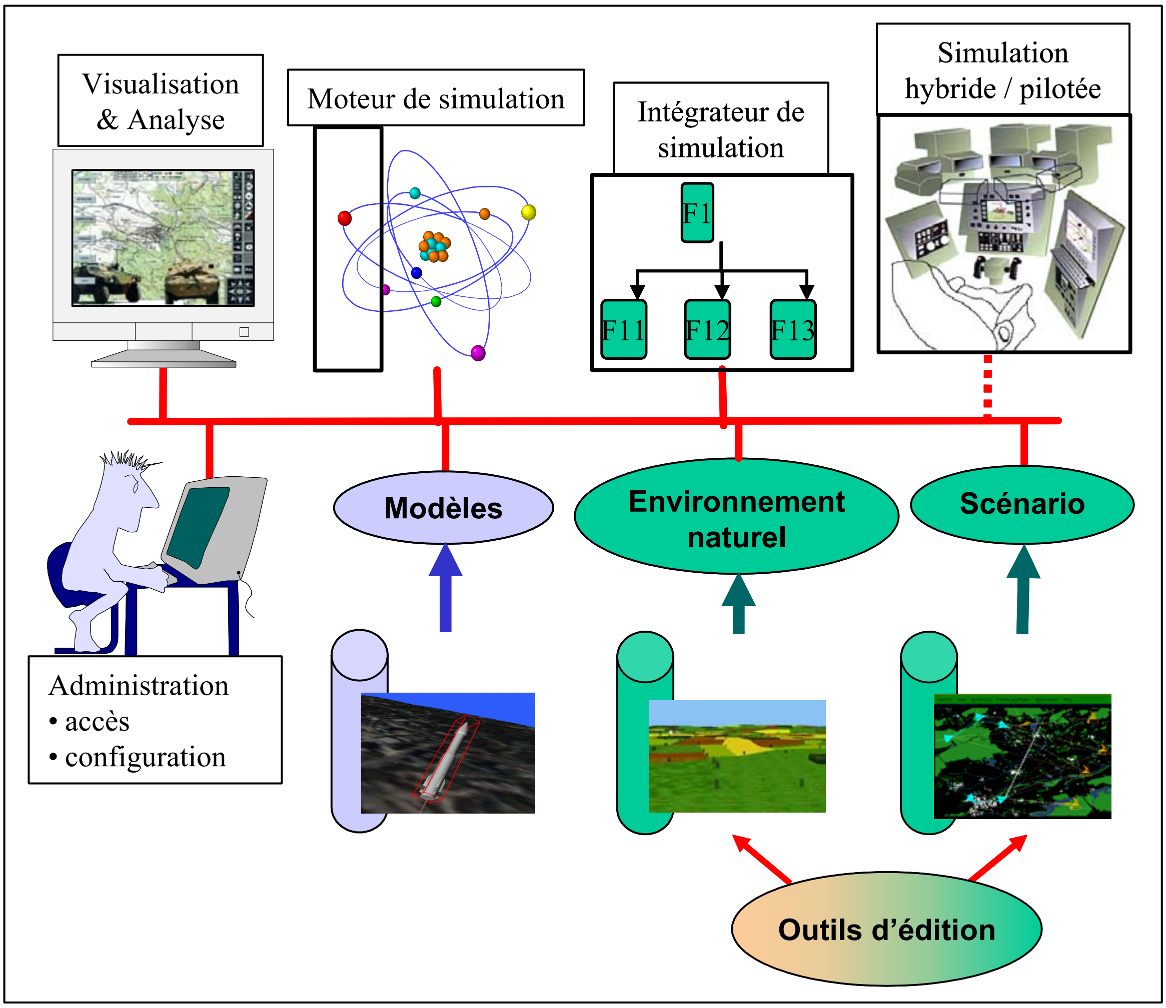

Figure 1: Synoptique de l'architecture de l'ITCS.

Ce synoptique contient les éléments constituant le noyau dur de l'ITCS dans sa première version :

- une fonction de capitalisation et de gestion de configuration, représentée par des bases de données, relatives aux modèles et aux données d'environnement naturel ou tactique ;
- des outils d'édition de scenarii et de conception de simulations ;
- des fonctions de visualisation et de post-traitement ;
- des utilitaires pour l'utilisation et l'administration de l'ITCS ;
- un moteur de simulation ;
- une fonction de communication, représentée par un réseau.

Comme mentionné précédemment, il est aussi prévu de prendre en compte dans la mesure du possible les simulations hybrides et pilotées dans l'ITCS, mais dans une version ultérieure de l'ITCS.

5.3 Planning des travaux futurs

Le cahier des charges élaboré dans la phase précédente servira de base pour mettre en compétition en 2003 deux maîtres d'œuvre industriels dans le cadre d'un marché de définition, avec pour objectif de définir une architecture technique répondant aux besoins exprimés. Les architectures proposées seront jugées en fonction de leur performance technique, de leur capacité à évoluer et à s'intégrer dans des architectures plus globales. Elles seront évaluées pour cela sur trois projets particuliers de simulations, qui seront déterminés afin d'obtenir une couverture aussi large que possible des activités que mène actuellement la DGA.

Mais le choix de l'une ou l'autre architecture candidate reposera également sur des critères économiques : il sera ainsi demandé une analyse technico-économique de l'infrastructure : coûts de déploiement et d'utilisation, prenant en compte aussi bien l'effort financier que l'effort lié à l'organisation et au changement d'outils et de méthodes.

Enfin, un troisième critère de jugement concernera les recommandations d'achats que devront proposer les industriels. Ces recommandations préciseront en particulier les contraintes d'interface liées à l'ITCS pour les futurs achats d'outils de simulation dans le cadre des programmes d'armement menés par la DGA. Elles constitueront une aide pour les équipes de programmes, et garantiront la cohérence et l'interopérabilité des différentes simulations.

À l'issue de cette compétition, la meilleure proposition devra être réalisée par son auteur, déployée progressivement sur les sites concernés à la DGA, et maintenue dans le cadre d'un marché unique. Il est prévu de déployer une version majeure par an sur l'ensemble des sites. Figure 2 précise le calendrier des travaux depuis la spécification jusqu'aux déploiements successifs sur les sites de la DGA.

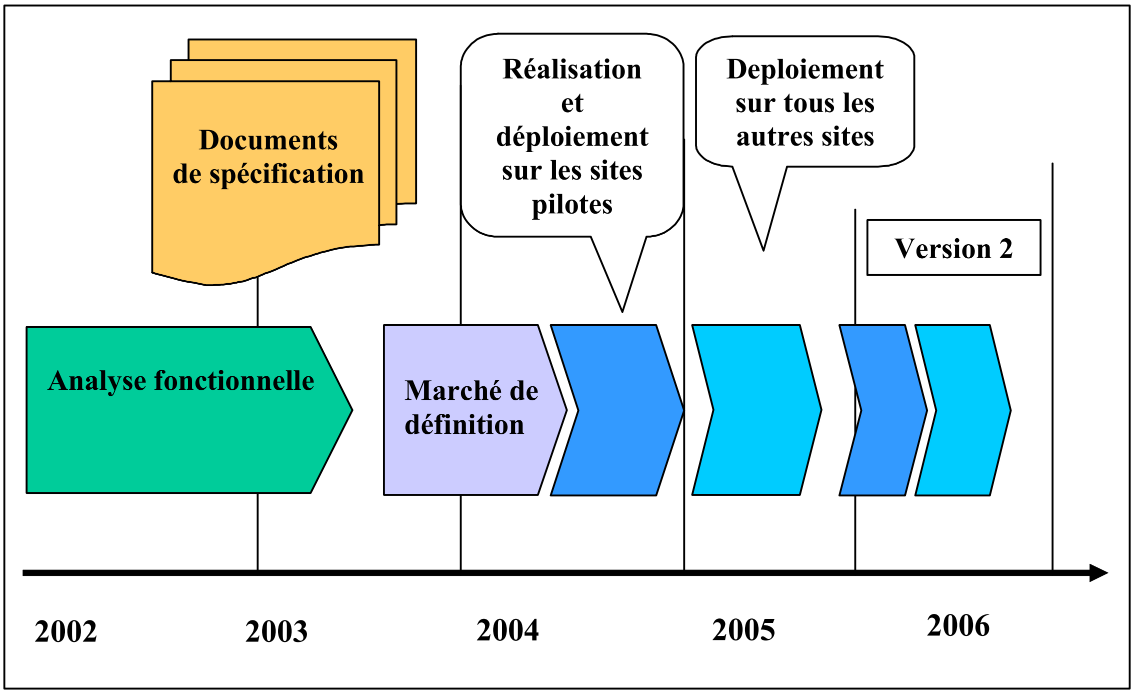

Figure 2 : Calendrier de réalisation de l'ITCS.

6.0 CONCLUSION

L'étude ARCOSIM-SA est un projet ambitieux, tant au niveau de ses objectifs techniques que du nombre d'acteurs impliqués. Mais c'est également un projet structurant et fédérateur dans la mesure où il mobilise toute la communauté M&S de la DGA pour développer un environnement commun de simulation, au profit d'une évolution des modes d'acquisition des systèmes de Défense.

À terme, l'ITCS contribuera donc de manière majeure au processus de simulation pour l'acquisition puisqu'il fournira un ensemble cohérent d'outils pouvant être mis en œuvre durant tout le cycle de vie d'un programme d'armement. L'ITCS contribuera également à uniformiser les méthodes et les processus, à développer une nouvelle culture chez les personnels pour la réussite de la simulation pour l'acquisition.

Cependant, d'autres efforts complémentaires sont également nécessaires pour son succès. Il faut mettre en place une gestion des connaissances (*Knowledge Management*), une politique d'acquisition cohérente et efficace à l'échelon central, et des formations aux technologies de M&S. Bref, la conduite du changement passe par l'évolution des cultures, tout autant que par la fourniture de solutions techniques adaptées et la redéfinition des processus.

Enfin, l'ITCS se veut être une infrastructure ouverte. Nous souhaitons en effet en faire un outil de collaboration avec nos partenaires industriels et nos alliés européens et de l'OTAN. C'est pourquoi nous avons souhaité exposer la quasi-totalité des études articulant ce projet, au risque de perturber le lecteur par certains détails peut-être superflus. Mais il nous apparaissait essentiel d'offrir une visibilité correcte sur un projet pluriannuel sur lequel la DGA investit financièrement, et qui nous semble un outil essentiel pour réussir la conception et la réalisation des systèmes de Défense d'aujourd'hui et de demain dans un cadre allant toujours davantage vers l'internationalisation et la répartition géographique des divers acteurs.

L'avenir nous dira si cette ITCS tiendra les promesses fondées en elle, et les premiers retours d'expérience de son utilisation concrète, qui devraient avoir lieu à partir de fin 2004, seront essentiels pour réussir le déploiement itératif et l'évolution éventuelle des versions suivantes.

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NIAG Study on Modelling and Simulation Support to Peace Support Operations (PSO)

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ABSTRACT

The central objective of this study sponsored by the NMSG was to identify practical, cost effective and realizable ideas to enhance NATO capabilities for managing the spectrum of Peace Support Operations by means of M&S. Planning, training and exercise, performing and analysis of employment in context with Peace Support Operations may be significantly improved (if not enabled) by the utilization of Modelling & Simulation (M&S). The mission space domain of Peace Support Operations enlarge the traditional Article V mission space. Several NATO nations have already study or simulation activities on M&S for PSO (Part of non-article-V operations for NATO or Operation Other Than War for US). An harmonization of the state-of-the art and an action plan for future NATO M&S capabilities was required in order to support NATO combined joint task forces on this new NATO tasks. This paper described the conclusions of the NIAG SG67 studies to identify the PSO M&S requirements and technical requirement issues to initiate NATO PSO M&S capabilities.

1.0 INTRODUCTION

The NIAG SG67 performed a prefeasibility study on Modelling and Simulation support to Peace Support Operations to define solutions and present a vision of a future simulation system addressing M&S systems for NATO and the Nations Peace Support Operations. This study – sponsored by the RTO/NMSG – will be followed by the Technical Activity Program (TAP) MSG-024/TG-017 of the NATO Modelling & Simulation Group (NMSG) to define the national contributions in accordance with a PATHFINDER "Vision" demonstrator.

The geopolitical changes, the new global economy, the population explosion, the food shortages, the climatic changes are just a few examples of threats which will require new military deployment. Rapid technological progress will contribute to in two aspects, one in facilitating the preparation and rehearsal of the potential scenarios, the other in providing an immediate feedback of the tactical events in the fields.

Internal or regional conflicts, threats by terrorists, radical political leaders, unstable regions and/or governments and natural/ environmental catastrophes may require diverse use of military forces. These uses are critical in their preparation and require multinational co-operations including the civil forces at the locations of conflict and worldwide. These uses of Forces are known by NATO bodies as: "Crisis Response Operations (CRO)". CROs fall into two categories:

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

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

The focus of this study is mainly on Peace Support Operations. However, consideration has been given as well to some relevant aspects of OSI, namely in the area of acts of terrorism including missile and aircraft attacks with their potential catastrophic consequences on alliance members.

PSO are those operations where military and civilian personnel are normally involved, to implement arrangements relating to the prevention of conflicts, to the control of conflicts (cease- fire, separation of forces etc.), to the resolution of conflicts (partial or comprehensive settlements), and to establish and protect the delivery of humanitarian relief in situations of conflict.

2.0 PSO SIMULATION NEEDS AND MODELS REQUIREMENTS

In accordance with the NATO M&S Master Plan V1.0 [4], the following needs are identified:

- Education
  - PSO principles, ROEs, International Laws, multinational issues, …
- Training
  - E-Learning tools with study cases (Recce, Surveillance, Rescue, command chain with fire/non-fire decision and consequence, patrolling,…)
  - Pre-deployment: force generation, medical resources, administrative needs
- Exercise
  - Crisis Management & Planning/Force generation exercises
  - NATO/PfP Joint Combined Exercises in PSO context
  - Tactical training (FTX, CPX, CAX)
    - Co-operation with IO/NGO, CIMIC Training, ROEs
    - Urban Operations (MOUT)
- Operational support tools: Logistic, Course Of Actions & Planning
  - Force generation for PSO or Low intensity conflict
  - Support tools for logistic, personnel, medicine
  - Decision aids (Consequences of actions, alternative issues)

The AJP-3.4.1 [1] highlights military capabilities relevant to PSO. These military capabilities will be used as initial list of PSO model requirements:

- Maritime
  - Maritime Patrol (Cease-fire line, embargoes, piracy/contraband control, …)
  - Amphibious operations
  - Maritime support (evacuation, logistic, humanitarian resources, counter-mine)
  - Fire support (to forces ashore)
- Land
  - Armour (Reconnaissance, surveillance, fire power, protection, mobility, …)
  - Artillery (Fire location radar, UAV, counter-fire, guided munitions)
  - Infantry (site protection, patrol, check points, search ops, riot dispersion, …)
- Air
  - Reconnaissance & Surveillance (Fixed-wing, UAV, Satellite; ELINT/SIGINT)
  - Air Transport (Inter-theater & tactical for troops, medical, food, SF, …)

  - Control of the air (Counter-air, air protection, air blockade, traffic control, …)
  - Offensive Air power (high value assets, avoidance of collateral damage, …)
  - Helicopters (Air transport, reconnaissance, combat support)
- Joint logistic
  - NATO Logistics (accommodation, food, water, petroleum, medical, …)
- Joint Capabilities
  - Special Forces (liaison, reconnaissance, …)
  - Engineers (Power supply & distribution, construction, repair, camp construction for forces or refugees, ordnance disposal for mines, …)
  - NBC (decontamination, recce/survey, terrorist act protection of plants/labs…)
  - Medical (services to forces & indigenous population, hygiene recce, media impacts, veterinary services specially for dogs and for foods)
  - Multinational Specialized Units (Military Police, Military Provost Staff)
  - Intelligence (HUMINT, data collection, night observation, special air surveillance)
  - Psychological operations (use of radio & television newscasts, …)
  - Public affairs (political & diplomatic goals, media, NGO/PVO, …)

There are significant commonalities between Article V tasks and Peace Support Operation tasks, some tasks are common (manoeuvre, deployment, logistic, engineering…), some tasks are new (checkpoint, provide communication between parties, provide legal services…). Moreover, the situation could change rapidly between PSO situation and war situation. Some military force equipment is used both for PSO and War and military organisations have some commonality (e.g.: CJTF), so simulations should model both Article V and non-Article V operations.

In order also to minimise the M&S investments a reuse policy of Article V existing maritime, land and air models is recommended for Land, Maritime and Air simulations. Following features are expected to be necessary:

- Representation of multi-parties
- Asymmetric Rules of Engagements
- Low engagement (e.g.: non lethal weapons or small arms)
- Additional and/or more detail terrain database features (e.g.: urban areas, infrastructures, …)

3.0 TECHNICAL REQUIREMENTS

The present study is complement to the flagship PATHFINDER programme of the NATO Modelling and Simulation Group (NMSG). This programme is tied to the original M&S Master Plan (MSMP) which is the base plan underpinning PATHFINDER activities. Pathfinder aims to provide more effective exercising and training for the CJTF through the creation of federations of national models, integrated with decision support tools, to conduct Computer Assisted eXercises (CAX) at Strategic and Operational Levels seamlessly integrated with NATO CIS.

The use of federations composed of different national models may offer enhanced detail, fidelity and realism (sought by Operational Commands) to the monolithic simulations that are employed today. Federations provide greater fidelity in each of the Air, Land and Maritime domains and they also offer the possibility of dynamically linking families of models with different levels of resolution. This multi-resolution approach enhances training value of the model and the ability to validate and improve NATO doctrine.

In order to identify potential PSO models, 3 sets of simulations and tools have been analyzed:

- Candidate PATHFINDER simulations : ABACUS, ALLIANCE (DUCTOR, STRADIVARIUS, WAGRAM), JCATS, JOANA (ALICE, HORUS, KORA, MEMO, SIMOF), JTLS, KIBOWI, SIACOM.
- Additional PSO models: AWARS, CATS, DEXES, DIAMOND, GESI, RAPHAEL/ABS-2000, SPECTRUM, TUTOR.
- Logistic, COA & Planning tools: ACROSS, ADAMS, COAST, COMPAS, GAMMA, SIAM, TOPFAS.

The main conclusions of this analysis are:

- No simulation and tool cover all the PSO requirements. They have a need for general purpose Art V with some non-art V capabilities and for Specific PSO area (PSYOPS, Urban operations, ….).
- They have a lack of common data model and model consistency. They have various data models and various level of granularity.
- They have a lack of CCIS interface. It is yet the case for conventional Art-V CCIS. For non-Art-V it is worst as PSO CCIS definition is just starting.

There is no CCIS specific data model for PSO; it is embedded within the Land C2 Information Exchange Data Model (LC2IEDM). Since the version 5.0 (which is the next standard to be published by ATCCIS at the end of the current phase, summer 2002), the LC2IEDM includes PSO requirements as asked by Operatives.

For initiate further M&S PSO the next steps are to:

1) Design first a M&S Reference Data Model. The work could start from LC2IEM V5.0, merge this data model with the NATO reference data model for joint operation, and extend also Air and Maritime data model for PSO to update this NATO reference data model. From the NATO reference data model, a scenario data model could be derived for M&S.
2) Continue this effort within the MIP in order to update the APP-9 standard. The AdatP-3 format is not very suitable for Simulation-CCIS exchanges (and CCIS interoperability remains an issue). XML technology should be more appropriate. Numerous PSO needs are also not addressed in the messages, so the data model has to be extend accordingly to the LC2IEM V5.0 for land or NATO reference data model for joint operations. This new APP-9 standard (format and data model) will be easier to integrate in the XML definition on the FOM accordingly with the HLA IEEE 1516 standard.
3) Make the FOM consistent with the CCIS Data Model. This problem has been identified by the SISO organisation, which has created the C4I Technical reference Model Subgroup. No international work is currently done on a reference FOM for operation and planning, except the work just starting with PATHFINDER. This work has to be complete and has to include also the PSO aspects.

Once these 3 steps will be achieved, and the level of effort to reuse legacy simulation for PSO and/or to develop new component will be estimated, a final tool selection could be perform in order to meet the simulation infrastructure defined for PATHFINDER applied to PSO needs.

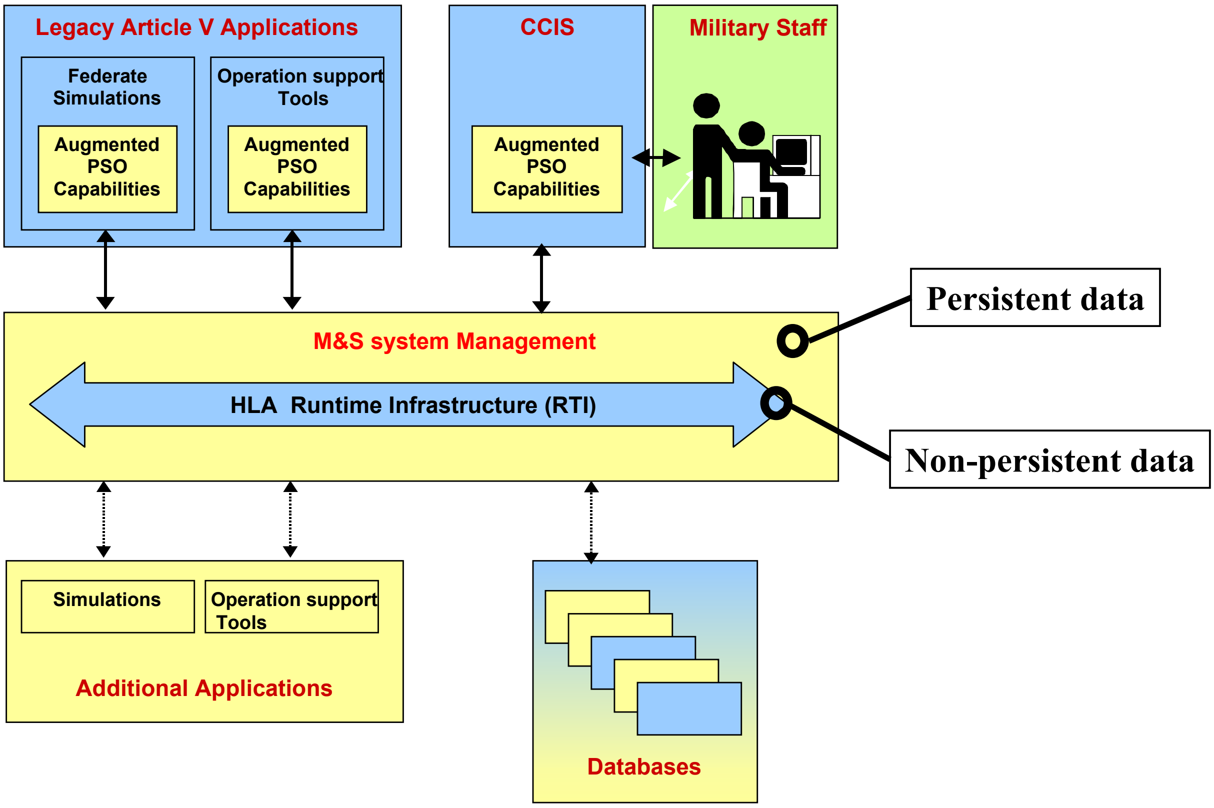

Figure 3-1: PATHFINDER vision of M&S Support to PSO Needs.

HLA techniques will be used to federate interactive application, once simulation database, operational support tool database and CCIS database will be aligned on a consistent scenario. A M&S system management will be required to exchange these "persistent data", versus the "non-persistent data" exchanged using the HLA techniques. The "non-persistent" data interchange techniques have to be defined (XML string exchanges based on CORBA mechanisms, database replication, etc.).

The architecture of such M&S support tool (see figure 3.2) is not specific to PSO applications and will be recommended as well for Art V applications. So, architecture development could start before to have completed the work on PSO data model. This architecture will include the M&S System, the CCIS system and the Simulation – CCIS interfaces.

Simulation-CCIS interface will be split in three categories of interface:

- Persistent data interface. A bridge will support the mapping between the CCIS data model and the simulations and tools data model (the reference data model will help the mapping process). This bridge will support also the existing CCIS data exchange mechanisms and the simulation data exchange mechanisms in order to reuse the simulation system in interface of the different NATO/National CCIS systems. On the simulation side SEDRIS should be the standard for environmental data interchange.
- Non-Persistent data interface. One or several bridges will support the mapping between CCIS message exchange or data link and the HLA federation. The FOM will be designed to support this mapping.
- Control interface. Further analysis is required to define this interface.

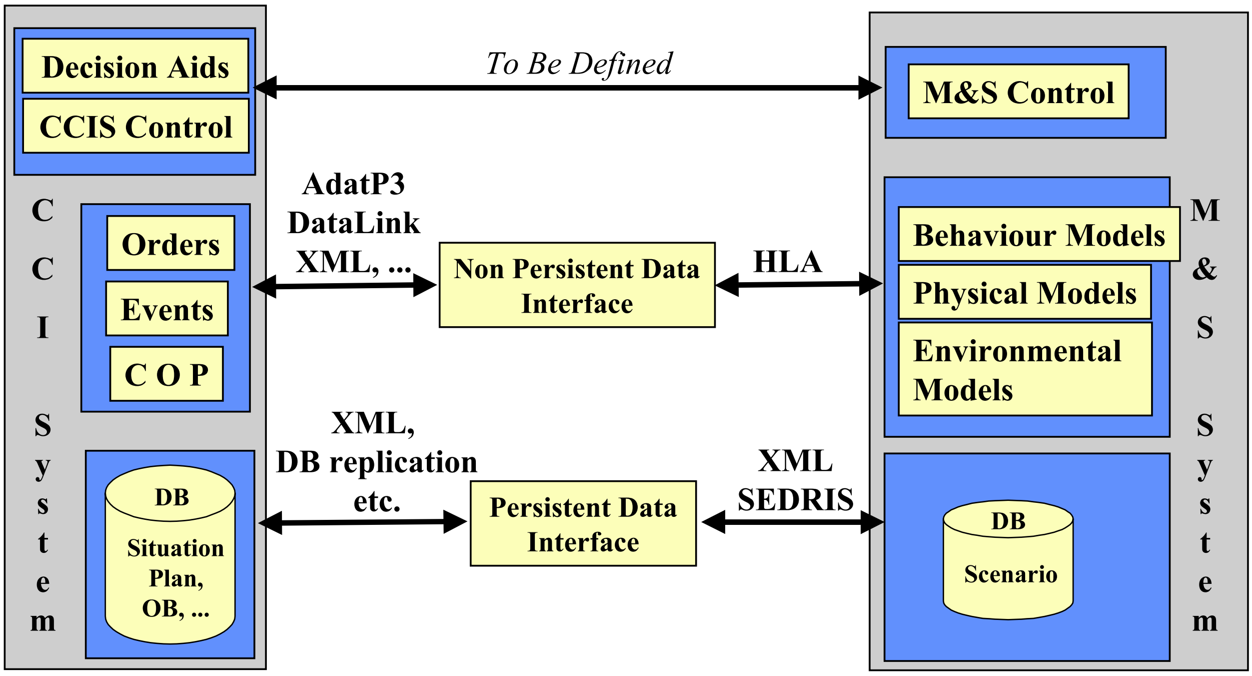

Figure 3-2: M&S Support Tool Architecture.

M&S system application will cover military exercises and operational support tools as defined in chapter 2.

4.0 M&S SYSTEM FOR COUNTER TERRORISM

As identified by the relevant RTO Ad Hoc group, M&S system for counter terrorism could be considered as a special application of the system described above. Nevertheless, the CCIS system change and the LC2IEDM data model is perhaps not appropriate, even if some commonality could be find, especially for Military Operation in Urban Terrain (MOUT).

M&S system for counter terrorism database will contain all Geographical Information concerning urban environment and vicinities: road, urban transportation, building, rivers, etc. Statistics information should include all information requested in crisis condition like: population density, traffics, building protections, smoke dispersion in function of weather conditions, etc.

Based on the information in the database, planning elements should contain:

- Potential Targets.
- Mediums (i.e.: all possible propagation ways of attack effects, following various scenario).
- Consequences (i.e.: direct risk and lateral effects).

Two different systems will use this database:

- The first one will help Crisis Management Leaders to react with a short reaction time.
- The second one will train civilian and crisis management workforce to react properly.

The first system (see figure 4-1) will be used in front of large high resolution screen, to allow all people to have the same view of the events. Users will be able in preparation phase to add features like potential targets and mediums. They can create scenarios, test reactions and find new counter measures, all at a strategic level.

That system will be used in case of real terrorism attack in order to estimate:

- Terrorist movements capabilities. The system should include characteristics of terrorist structures and their transportation means. It will help to prevent other terrorist attacks or help to capture them.
- Human protection. Experience has shown that protecting workforce is very important. Such work means knowing where are the protective devices, how to distribute them, when and where to use them.
- Site recovery. A safety management system must be set up as soon as possible to do hazard monitoring, safety-equipment logistic and maintenance, site access control, health and safety monitoring, medical treatments. The safety management system can use all kind of available map (civil, military, from owner/operator), aerial photography, satellite imagery, statistical information to set up its database.

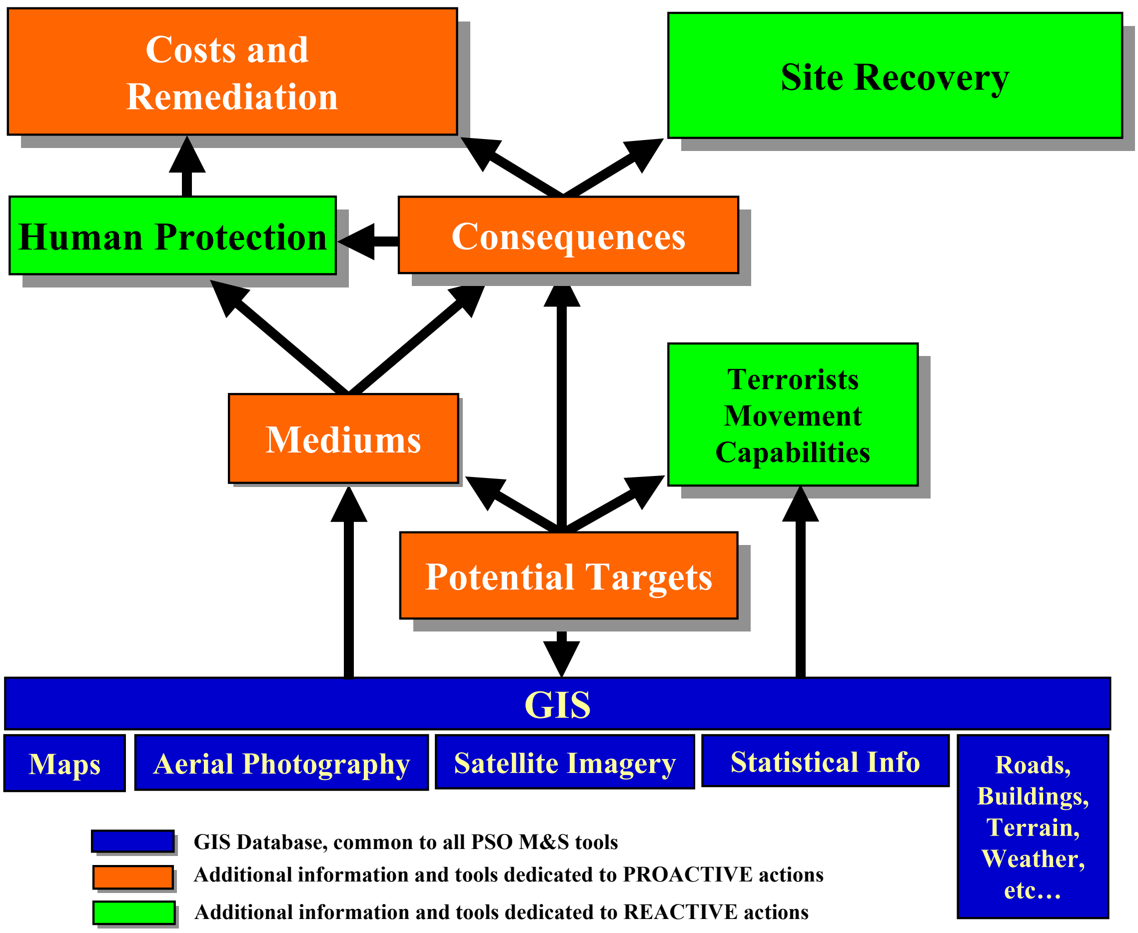

Figure 4-1: Counter Terrorism Operational Support Tools.

The second system (see figure 4-2) will be used to train and assess civilian and crisis management workforce with "real life" conditions, by using virtual reality. The virtual reality model will be extracted from the database, meaning that the database should contain, when available, as much as possible 3D drawings of existing infrastructure. All the potential people involved in counter terrorism measure will be able to train in that environment, even together at the same time. The system will be very easy to use and will not require more than 5 minutes to be set up.

There are new virtual reality software coming on the market, able to handle polysoup (plain Computer Aided Design file) and massive models coming from GIS and AEC (Architecture Engineering and Construction) CAD software. By automatically converting these models, previously stored in the general database, it is possible to quickly create realistic environment where safety training can be carried out.

CROSSES (CROwds Simulation for Emergency Situations) is an example of simulation system using 3D views of « real » reconstruction of an actual urban environment in order to develop emergency plans.

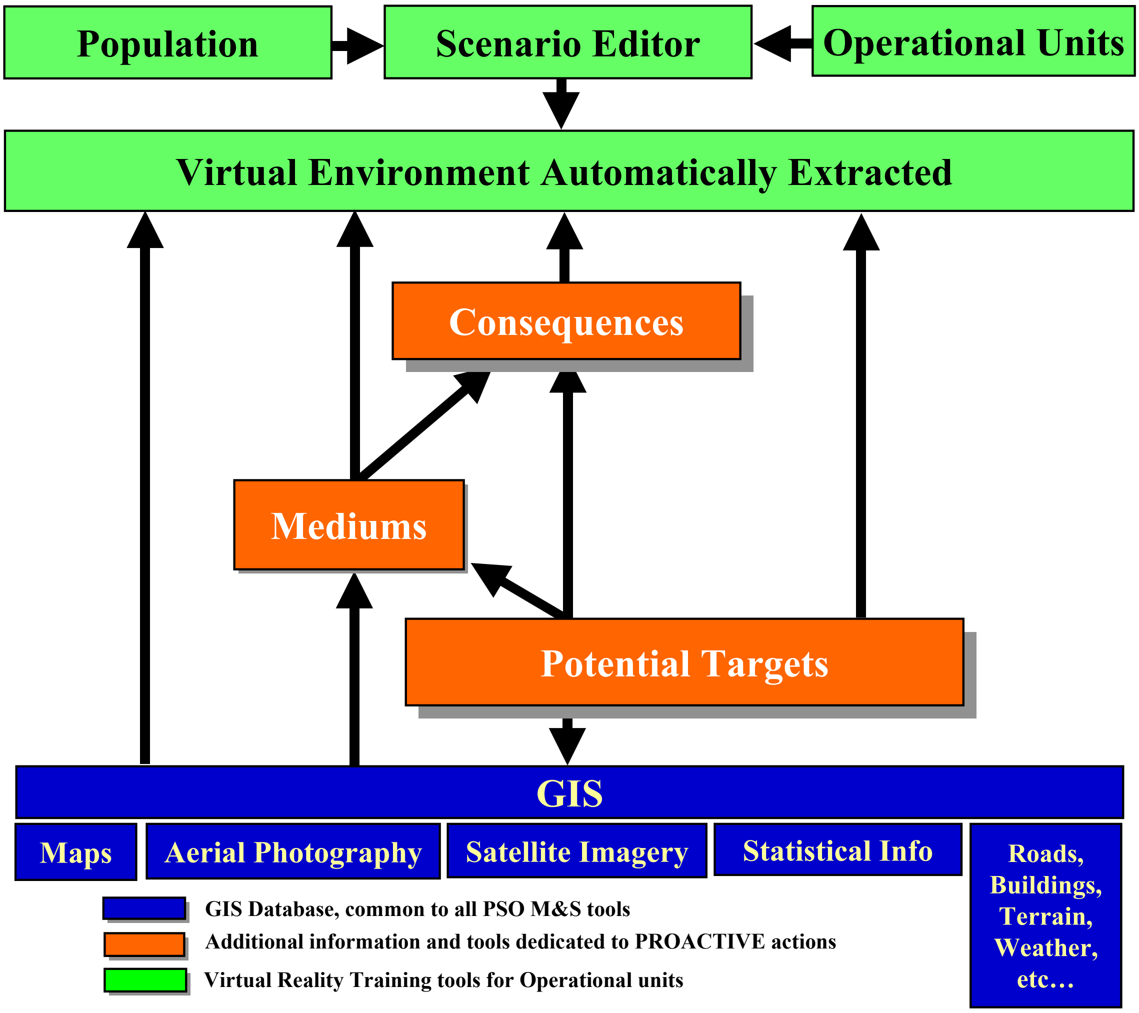

Figure 4-2: Training Version of the Counter Terrorism Support Tool.

Figure 4-3: CROSSES – CROwd Simulation System for Emergency Situations.

5.0 ROAD MAP AND CONCLUSIONS

For further developments 4 mains M&S actions are identified:

1) Specification of PSO applications.
2) Development of a Reference Scenario Data Model & Reference FOM. The data model and the FOM will be consistent with Peace Support Operation data model for CCIS.
3) Prototype a M&S simulation infrastructure with CCIS-Simulation interfaces for CJTF training and operation planning.
4) Prototype M&S based Counter-terrorism operation support tools.

The 3 first actions are preliminary to a M&S support to PSO demonstrator. The last one is a separate action: different users, different techniques and different simulations.

The SG67 team suggests MSG to support these actions by existing (or new) TAPs. For existing TAP the suggestions could be:

1) MSG-024 "Non-Article V Operations/ Course of Action Analysis Tools" to lead the specification of PSO applications.
2) MSG-018 "Rapid generation of scenario' to support the development of a reference scenario data model in liaison with eMIP and concerned NATO organisations on CCIS Reference Data Model.
3) MSG-027 "Pathfinder Vision" to support the M&S simulation infrastructure.
4) MSG to set up a Technical Activity Program on Counter-Terrorism operations support tools in liaison with the Exploratory study MSG-ET-005 M&S Tools for the Early Warning and identification of Terrorist Activities.
5) Initiate the development of reference FOM(s) in the PATHFINDER applications and complete the development in the PSO demonstrator in order to take in account the Reference Scenario Data Model for consistency between non-persistent and persistent data model.

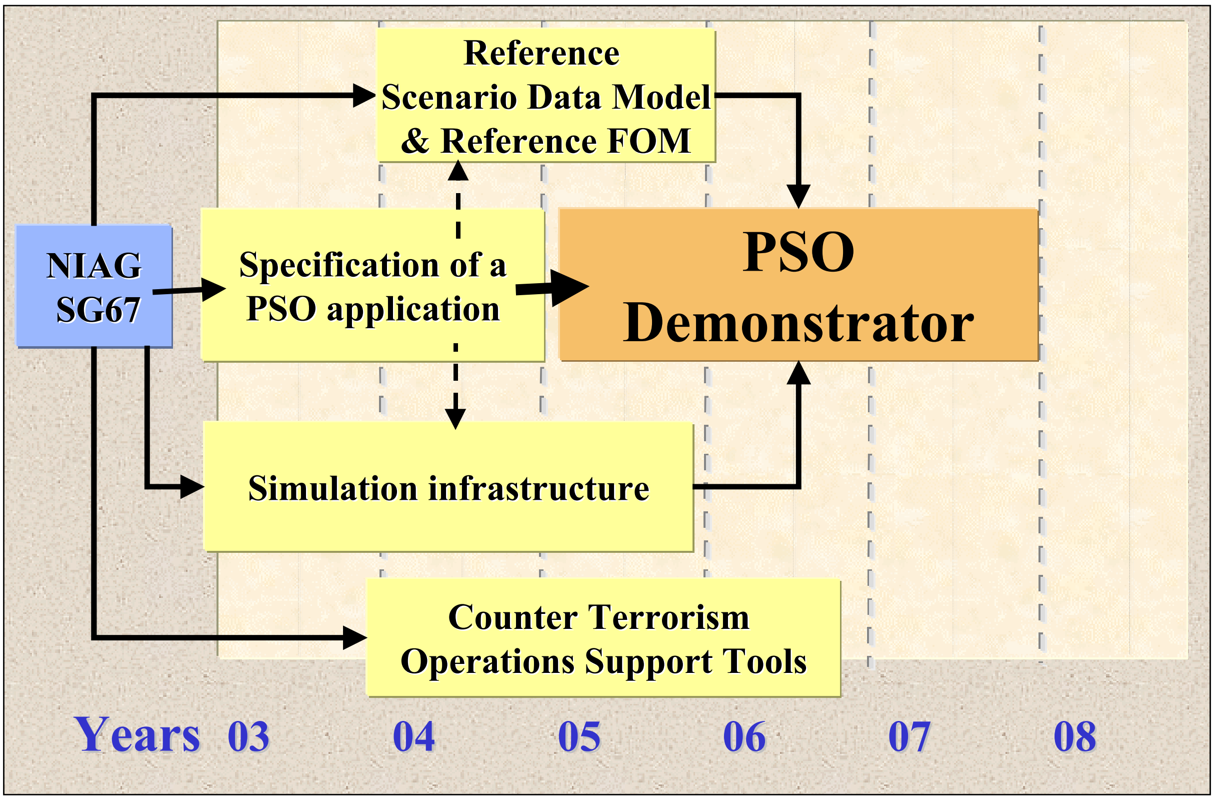

Figure 5-1: Action Plan Road Map.

6.0 ABOUT THE NIAG SG67

The NATO Industry Advising Group – Sub Group 67 is a group of NATO industrial experts in Modelling and Simulation working together on Pre-feasibility study on Modelling & Simulation support to Peace Support Operations. Starting in August 2001 and ending October 2002, the study report and available materials are distributed through the RTO/MSG (sponsor of this study) and NIAG.

Key SG67 positions are:

- Chairman: Jean-Pierre FAYE
- Deputy chairman: Dieter STEINKAMP
- Secretary: Bruno DI MARCO

Full member list, companies and National Points Of Contact are provided below.

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CZ	Martin KLICNAR	VR Group	X
FR	Jean-Pierre FAYE	ThalesRaytheon Systems	X
	Olivier MEYER	EADS/S&DE	
GE	Hans-Jürger MEYER	CAE Elektronik Gmbh	
	Christoph HAMPE	STN-ATLAS (retired)	(X)
	Dieter STEINKAMP	IABG (Previously CCI)	X
	H.J.SCHIRLITZKI	IABG	
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	Frederico CONTRERAS	INDRA	X
UK	Joelle DUMETZ	THALES Training & Simulations	X

Figure 6-1: NIAG SG67 Members.

7.0 REFERENCE DOCUMENTS

[1] AJP-3.4.1. "Peace Support Operations" July 2001 (STANAG 2181).

[2] ATP-3.4.1.1 "Peace Support Operations Tactics, Techniques and Procedures".

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[4] NATO M&S Master Plan.

[5] Joint Task Force Commander's Handbook for Peace Operations, Joint Warfighting Center, Virginia, 16 June 1997.

[6] ARTEP 100-23-1 MTP. "Mission Training Plan for the Division Headquarters Command and Staff in Conducting Stability and Support Operations in Bosnia (Peace Support)", Headquarters, Department of the Army, June 2000.

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A M&S Process to Achieve Reusability and Interoperability

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ABSTRACT

This paper presents a modelling and simulation process based on state-of-the-art software engineering concepts, tools and best practices. It aims at guiding modellers in the development of extensible, reusable and interoperable models to be used in integrated simulations. Although this process has a very broad reach, it is incubated in a project for weapon system engagement simulation in order to better focus its application. The first iteration of the process development, which is reported here, is aimed at assessing the validity of the proposed concept. It was observed that despite the availability of tools and guidelines, no successful and cost-effective simulation is possible without teamwork, communication, common infrastructure, agreement, education, constraints and integration.

1.0 INTRODUCTION

In the context of defence related research and development, Modelling and Simulation (M&S) is often used as a tool to obtain precise answers to very specific questions. Due to time, resource and expertise constraints, several models or simulations are commonly developed in an executable format, with few customisable elements, to satisfy very specific requirements. Consequently, a more or less significant model rework is required for even slightly different applications. Another common weakness is the lack of rigorous, common and enforced modelling method, which often produces non-reusable and non-interoperable models.

The actual quest for a global synthetic environment is a catalyst to increase the span of M&S benefit. In this new vision, the real world is represented as a virtual environment where autonomous entities, behaviours, terrain, environment and information interact dynamically. A specific simulation only observes a subset of the entire environment. This conceptual approach may lead to some solutions to the M&S reusability and interoperability problem. However, the demanding system integration needs to be supported by effective teamwork and large-scale software development methods applied to the M&S domain.

From this point of view, new requirements for successful and cost-effective M&S include reusability, extensibility, portability, modularity and interoperability. Recently, the software engineering domain has tackled these problems with success. Therefore, since M&S relies on software applications, these novel M&S requirements could be fulfilled using state-of-the-art software engineering concepts, tools and best practices.

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

This paper proposes an integrated M&S process to guide the modellers in the development of reusable and interoperable models to be used inside extensible simulation frameworks. The proposed process has been initiated by modellers from the engineering and engagement levels, at the bottom of the M&S levels pyramid (Figure 1). The team adopted a vertical approach and focussed on the modelling process. Model engineering [1] is essential to create models for high-fidelity sub-system simulations as well as for a higher-level synthetic environment. Emphasize was then on potential uses for the models instead of specific deliverables, which implied that modellers had to understand the different contexts in which their models may be useful.

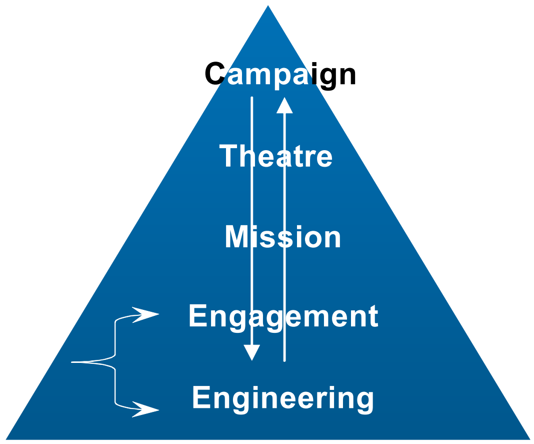

Figure 1: The M&S Levels of Detail Pyramid [2].

However, since modellers are rarely software engineers, an integration specialist is required. To foster the application of the proposed process, this person must understand the physics and the software aspects of the problem. It stresses the point that, to maximize reusability and interoperability, the bottom of the pyramid must understand the top and the top understand the bottom. For instance, the modellers must accept to be constrained, to some extent, to ensure that their models will be reusable and interoperable. The process must allow the modellers to focus on what they are good at, the modelling of physics.

This paper first describes the proposed M&S process and, afterwards, its practical implementation using specific software tools. The results section explains the incubating project surrounding the development of this process. Finally, the concluding remarks presents the lessons learned from the development and application of the proposed M&S process.

2.0 THE PROPOSED M&S PROCESS

As shown on Figure 2, the typical phases of any simulation are: modelling, execution and analysis [1]. The proposed process takes place to complement the M&S development theory in guiding the M&S teams in its concrete application. It essentially relies on software engineering concepts, tools and best practices applied to the M&S domain.

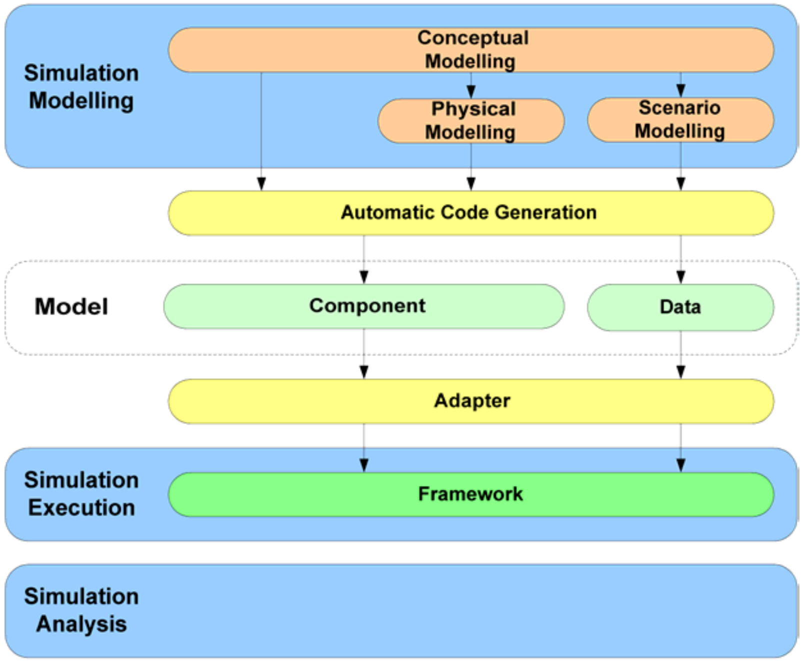

Figure 2: The Proposed M&S Process.

This is also an iterative process in the sense that the top-down integration can be restarted at any time in the development of a simulation and be completed within a few minutes time scale. In the software engineering domain, it is often called a micro-process spiral life cycle [3]. The automated steps standardize and speed up the model development process.

2.1 Simulation Modelling

The simulation modelling includes three main activities: 1) the conceptual modelling of the elements to be simulated; 2) the modelling of the physical behaviour of each element; and 3) the modelling of the scenarios describing the interaction between the various elements.

2.1.1 Conceptual Modelling

Conceptual modelling [1] is the first step of any structured M&S process. It is the abstraction of the entities, properties, behaviours and interactions to be simulated. In the proposed M&S process, the conceptual modelling is the reference of design. It means that modellers shall always go back at this level to make any changes. From a very high level perspective, representing the simulation requirements, it is possible to progress toward a model closer to the implementation.

In a software engineering approach to M&S, modularity and reusability can be expressed using the object-oriented (OO) paradigm and the component-oriented approach. As a standard for representing these concepts, the Unified Modelling Language (UML) [4] was selected to support the conceptual modelling. Therefore, applications of the simulation are described using “use case” diagrams while the static and dynamic aspects of the simulated system are represented using “class” and “sequence” diagrams, respectively. Finally, the implementation of the system is conceptualized using “component” diagrams. A consequence of this approach is the fact that modellers must be educated on UML and object-oriented programming to agree on a common conceptual model.

Design patterns [5] and domain specific standards, such as the Real-Time Platform Reference Federation Object Model (RPR-FOM) [6] in defence M&S, are also introduced at this level to synthesize reproducible and globally accepted concepts.

A simulation developed with the proposed process gains its extensibility from the incremental additions at the conceptual model level. This process fosters reusability by inviting the modellers to extract the commonality of their models. It also promotes interoperability by forcing them to agree on standard concepts and interfaces.

2.1.2 Physical Modelling

Physically based modelling [7] is the mathematical representation of the real world behaviour. In order to remain at a manageable complexity level, the physical models are tailored to satisfy specific use cases. Various physical models may then be necessary for different applications, which is also called multi-modelling [1][8]. This concept is essential for bottom/up and top/down reusability of models in the M&S pyramid (Figure 1).

Once the stakeholders agree on requirements and the modellers agree on concepts (entities and interactions), each specialist can model the physics that is under its responsibility. Stand-alone work is possible at the condition of strictly respecting the conceptual model or updating it appropriately if a modification is required.

At the final stage of the physical modelling, the model is implemented into a software format. The software model can be directly written in an object-oriented programming language or encapsulated into a class if it is a legacy model. However, since modellers are not necessarily programmers, it is often impossible to require structured and standardized code from them. On the other hand, they can be assisted by automatic code generation tools providing a standardized code skeleton limiting the code to be written. Visual programming and simulation tools are also favoured for physical modelling without specific programming skills. Indeed, these tools were especially created for specific domain engineering-level rapid prototyping, test and validation. They often allow the reuse of functionalities through common libraries and the interoperability with other specialists. The only constraint is then to design physical models compliant with the OO and component-oriented conceptual model and to break the functionalities into discrete, more or less fine-grained, modules. The main challenge resides in switching from block and wire to object thinking and to manage the time steps synchronization between the integration schemes.

2.1.3 Scenario Modelling

The execution of a simulation requires the prior modelling of the scenario. In the OO approach, conceptual and physical modelling are dealing with generic objects while scenario modelling refers to instances of these objects. It typically includes the specification of model parameters, initial conditions for the state variables, the dynamic assembling of sub-models composing higher-level models, the recording of output results and the instantiation of objects composing a simulation scenario.

Scenario modelling generates the data characterizing the simulation. By scripting, in opposition to hard coding, these elements, it is possible to reuse parameters and initial conditions, to select the output to be logged and to dynamically compose, at run-time, the parts of a model or the entities of a scenario. A standard and flexible data format, such as the eXtensible Markup Language (XML) [9], can significantly fosters the exchange, the modularity and the portability of these data.

2.2 Automatic Code Generation

To automate and speed up the M&S process, software tools can generate the code of the model components and data. This practice promotes software quality and model consistency. The model code generation can be done directly from the conceptual model. This option involves a manual intervention of the modeller to include, in the skeleton, his physical model written in the appropriate programming language.

Alternatively, the modeller can use a visual programming tool to develop his physical model and, afterwards, automatically generate the model code including all the behaviours. This option allows reusing the visual prototype to produce the final model components. Similarly, a tool associated to scenario modelling can automatically generates the model data.

2.3 Model

The outcome of the modelling phase is a software model that includes a component and its associated data. The component is the generic software implementation of a model while the data contains the features of each instance. For example, the simulation of two different instances of a model can be achieved by using the same model component with different data files.

To maximize the model modularity and reusability, the components must encapsulate fine-grained generic code modules. Moreover, in order to optimize the modeller's efforts, the components shall contain physical model code independent of any simulation framework. In practice, components are generally compiled in a library that can be dynamically instantiated and linked at run-time.

Model data specify what is left generic in the model components, each component having customizable parameters and initial conditions. Parameters are the model data that remain constant over the simulation while initial conditions change over time.

Entities are container models that can be dynamically composed of part models using configuration files. Similarly, simulation scenarios are composed of entity models with their respective configuration files.

2.4 Adapter

To maximize reusability, the generic models and data files are adapted (from the "Adapter" design pattern [4]) to specific simulation frameworks. The adapter relationship with the simulation framework and the model component is shown on Figure 3. An instance of the adapter is required for each instance of a model entity.

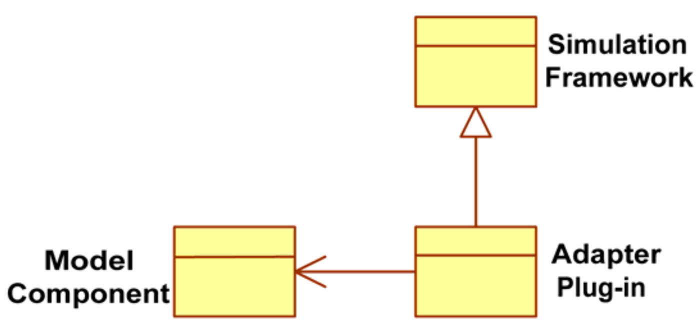

Figure 3: The "Adapter" Concept to Integrate a Model with a Framework.

Theoretically, the adaptation is possible with any OO and component-based simulation framework. However, a different adapter must be built to fit each specific framework. For a particular framework, the anchoring points can be limited to one or a few adapters depending on its extensibility and the compliance of the concepts between the custom models and the framework. Depending on the architecture and the complexity of the interaction, a variable level of effort may be required to benefit from the various built-in functionalities of a framework.

Practically, a model adapter is programmed using the Application Programming Interface (API) of the selected simulation framework and inserted into it as a plug-in. It acts as a dynamic model component interface with the simulation framework. The association of the model with the framework then does not require any recompilation and, depending on the framework, it may be run-time selectable. Scenario data file adapters can take the form of import/export capabilities.

Adapters have the advantage of reducing the dependence on a particular software product or environment. They contribute to improve the reusability of generic models, the modularity of the dependence to simulation execution and the extensibility of the simulation framework.

2.5 Simulation Execution

In the proposed process, the simulation execution is delegated to an existing commercial-of-the-shelf (COTS) framework that provides functionalities such as scenario creation, execution control, doctrines, trajectory, viewers, etc. Some frameworks may even include built-in model components and data. This approach originates from the fact that the expertise of the process initiators mainly resides in simulation modelling not in time management, distributed simulation, terrain database, visualization, etc.

The use of a recognized simulation framework contributes to the interoperability between the modellers by providing a common infrastructure. Within the defence community, such interoperability may also be improved if the chosen framework is compliant with the High-Level Architecture (HLA) [10].

2.6 Source Control and Web Page

The proposed M&S development process needs to be supported by version control, ownership tracking and exchange functionalities to ensure the integrity of the information. This can be achieved using, for instance, a shared database and a project web page. This practice shall be applied through the entire M&S process including: the conceptual model; the visual prototypes; the source code; the model components; the data files; and the documentation.

3.0 THE M&S PROCESS SUITE OF TOOLS

Practically, several software engineering tools are required to support and automate the proposed M&S process. An option analysis was carried out to determine the most appropriate suite of tools to demonstrate the proposed process. Some are COTS solutions and others are custom tools especially developed to be as generic as possible. It should be noted that these tools are not a unique solution but represent the best compromise when the option analysis was conducted. The automatic integration of these tools prevents subjective manual operations, promotes the iterative refinement and accelerates the process. Figure 4 shows the software tools associated to the M&S process while Figure 5 presents screen snapshots of the different tools.

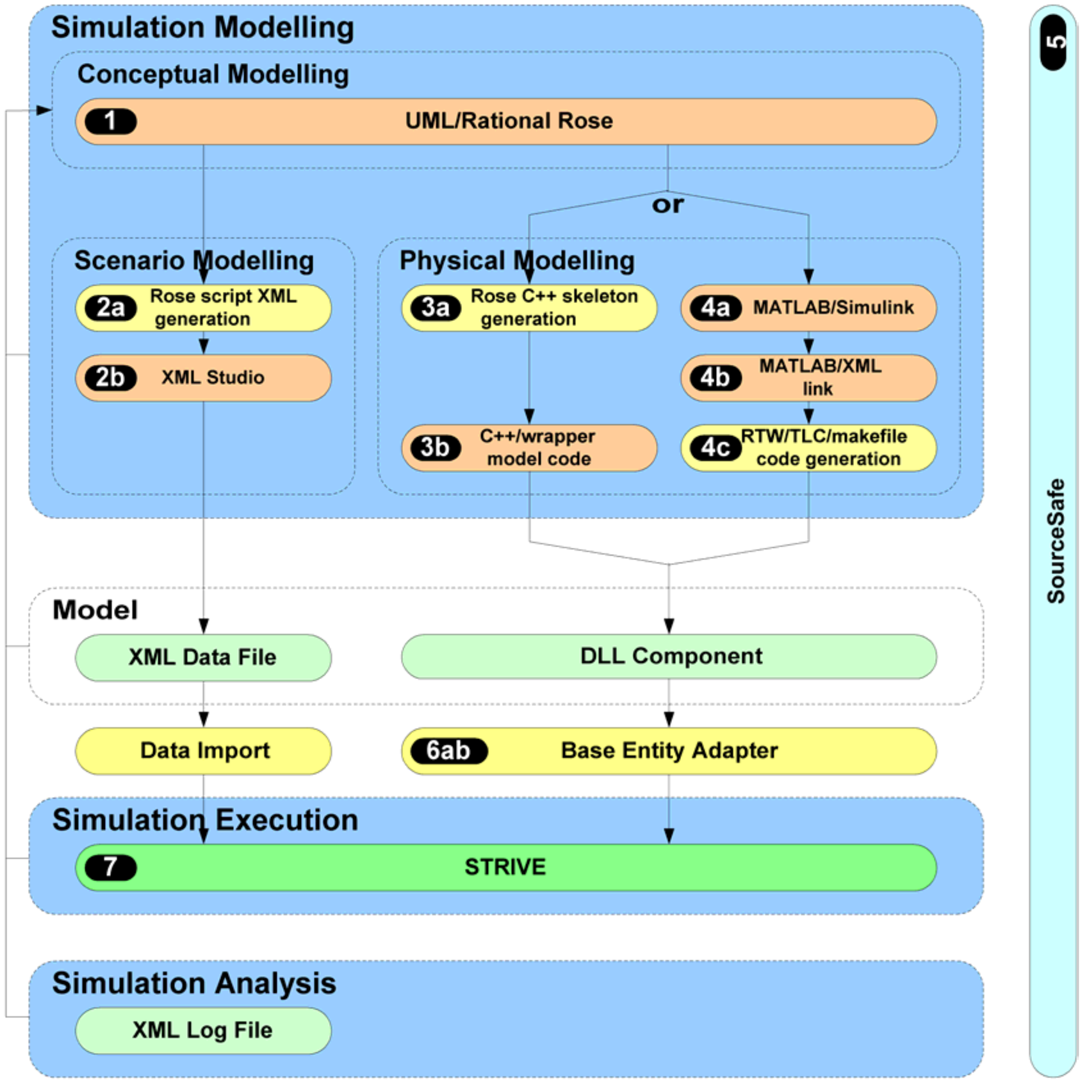

Figure 4: The Concrete Steps Implementing the Proposed M&S Process.

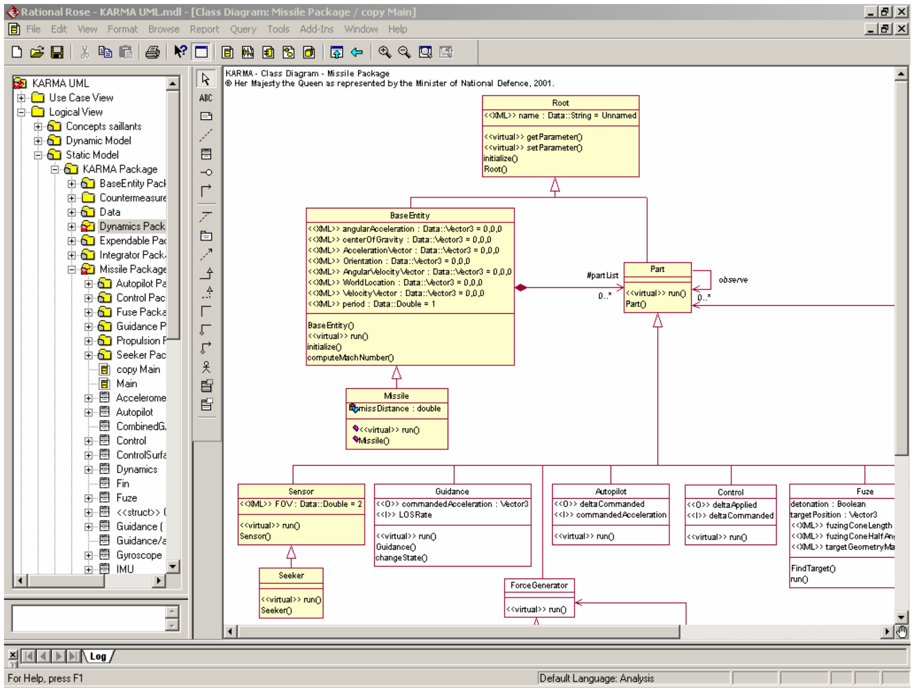

Figure 5a: Step 1 – Agreement on a Conceptual Model in UML with Rational Rose®.

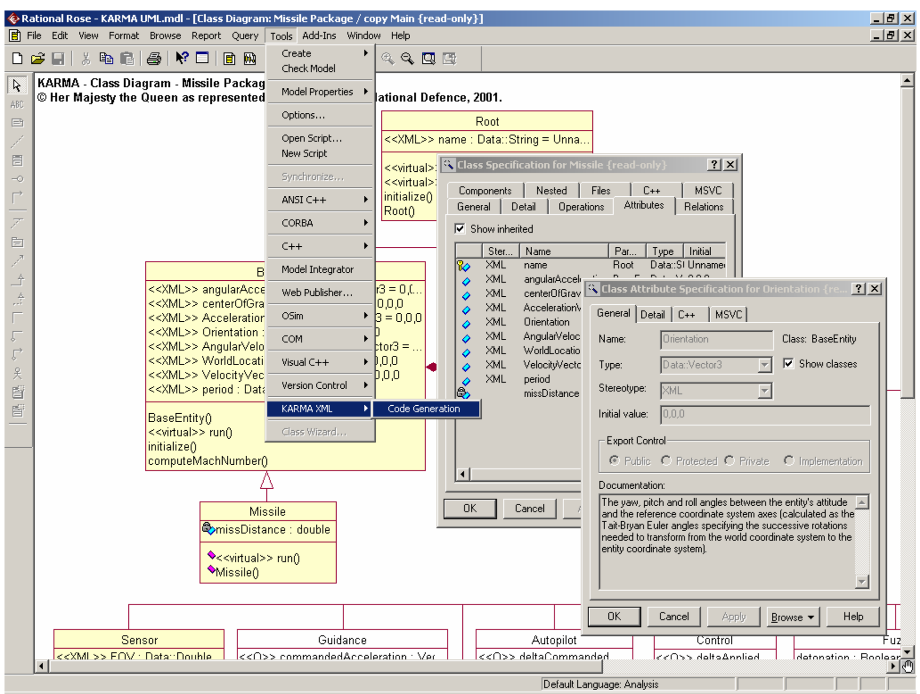

Figure 5b: Step 2a – Generation of XML Default Parameters Files from Rational Rose®.

Figure 5: Screen Snapshots of the Tools Supporting the M&S Process.

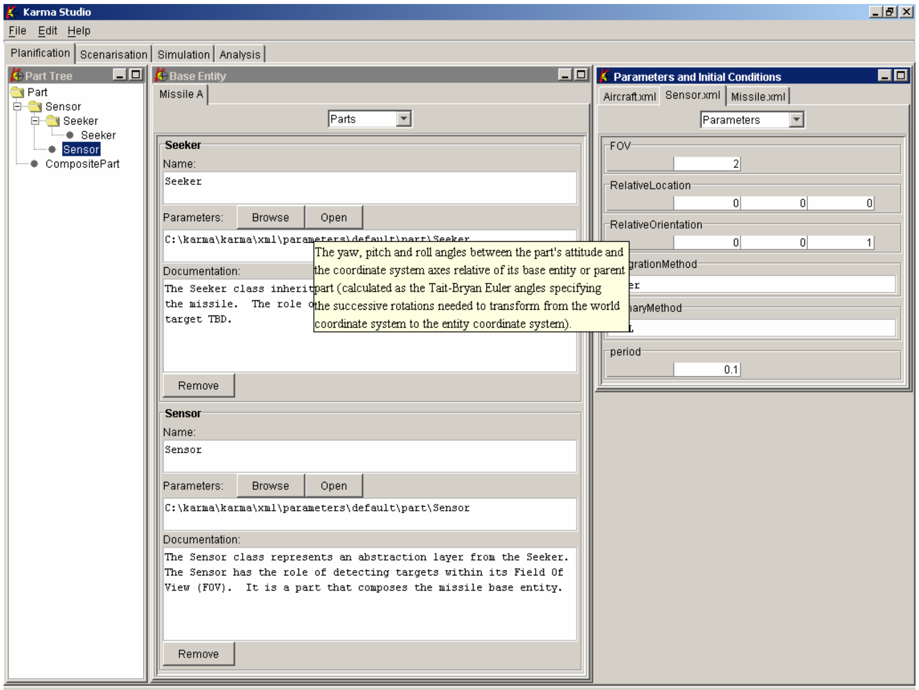

Figure 5c: Step 2b – Edition of the XML Scenario, Parts and Parameters Files in the Adaptive Java Studio.

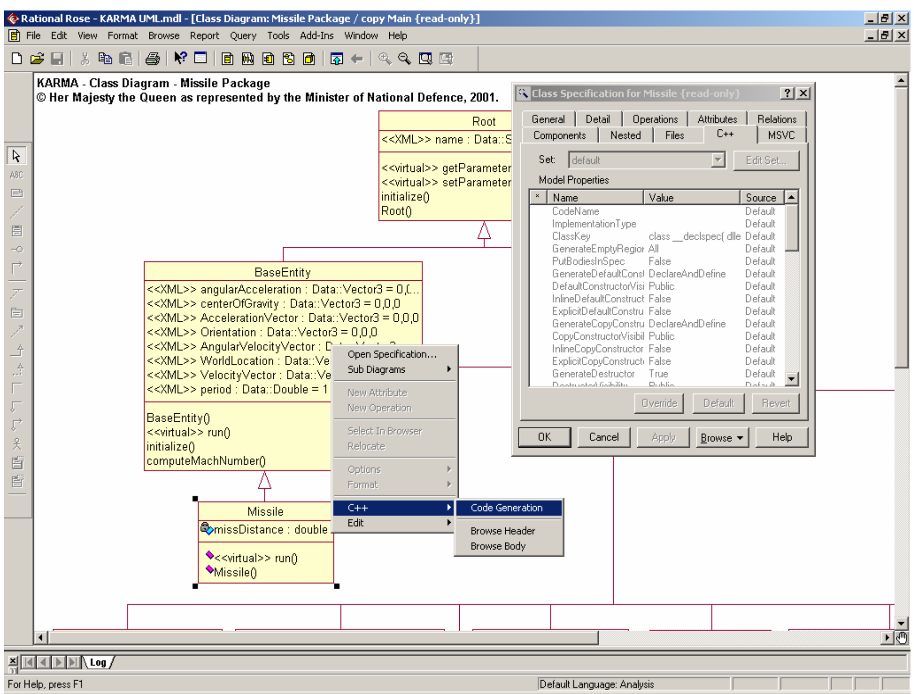

Figure 5d: Step 3a – Generation of a C++ Skeleton from the UML Conceptual Model with Rational Rose®.

Figure 5 cont'd: Screen Snapshots of the Tools Supporting the M&S Process.

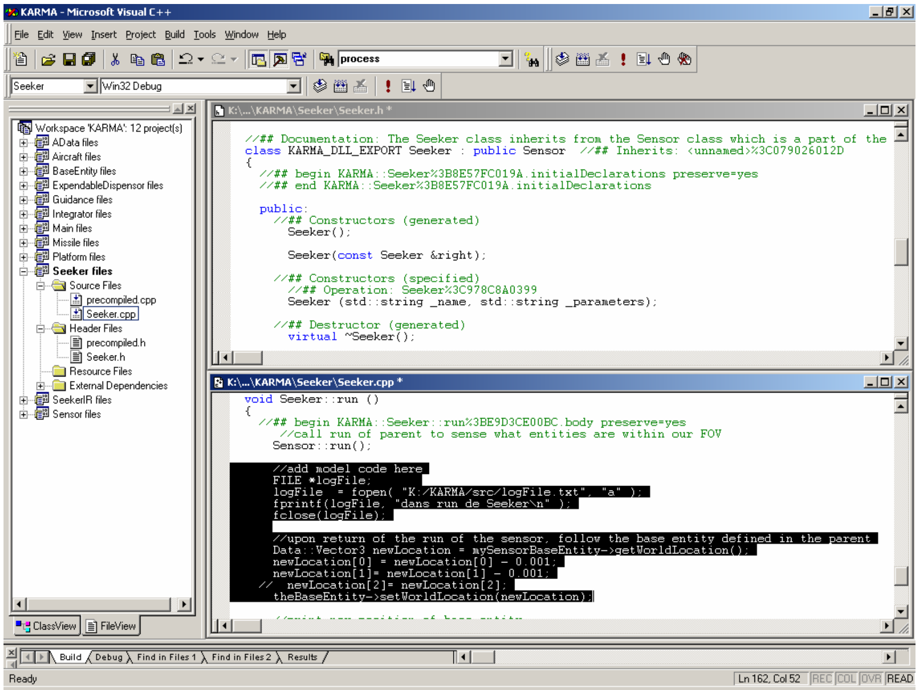

Figure 5e: Step 3b – Filling the C++ Skeleton with a Physical Model in C++ or Wrap a Legacy Model.

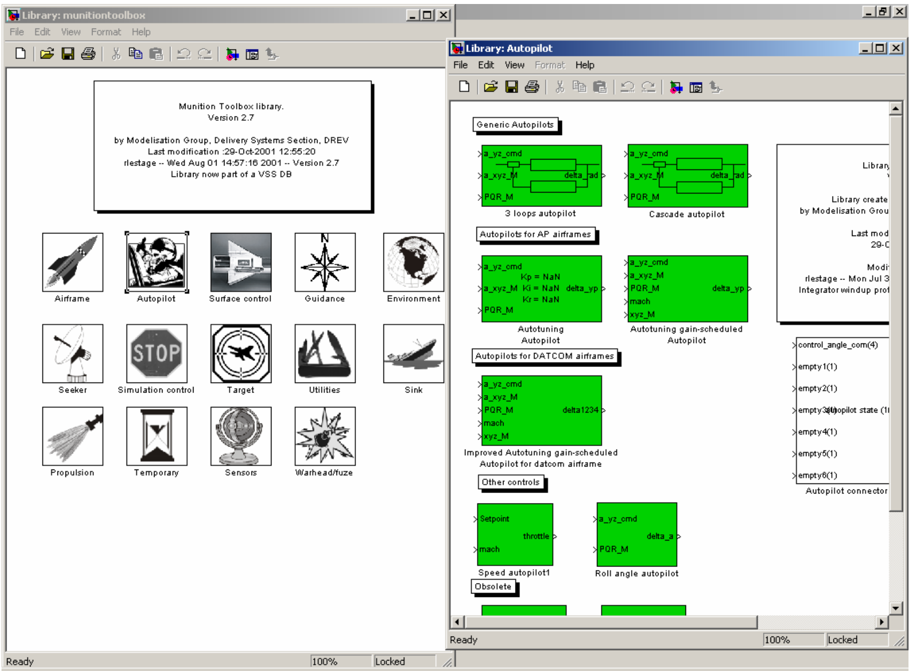

Figure 5f: Step 4a – Prototyping the Physical Model in MATLAB/SIMULINK®.

Figure 5 cont'd: Screen Snapshots of the Tools Supporting the M&S Process.

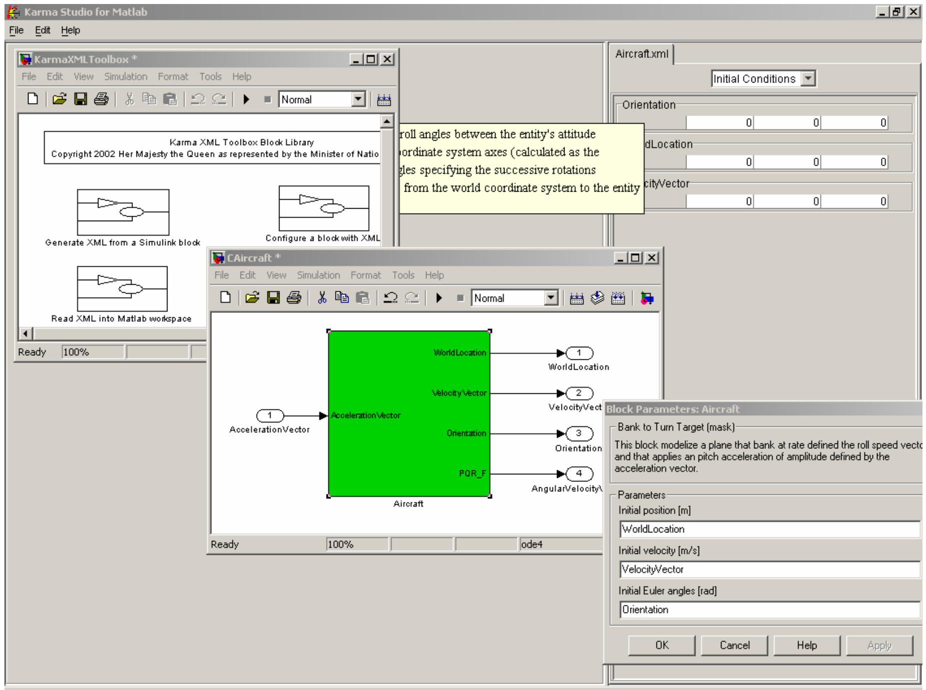

Figure 5g: Step 4b – Associating the SIMULINK® Model with XML Data Files Using the XML Toolbox.

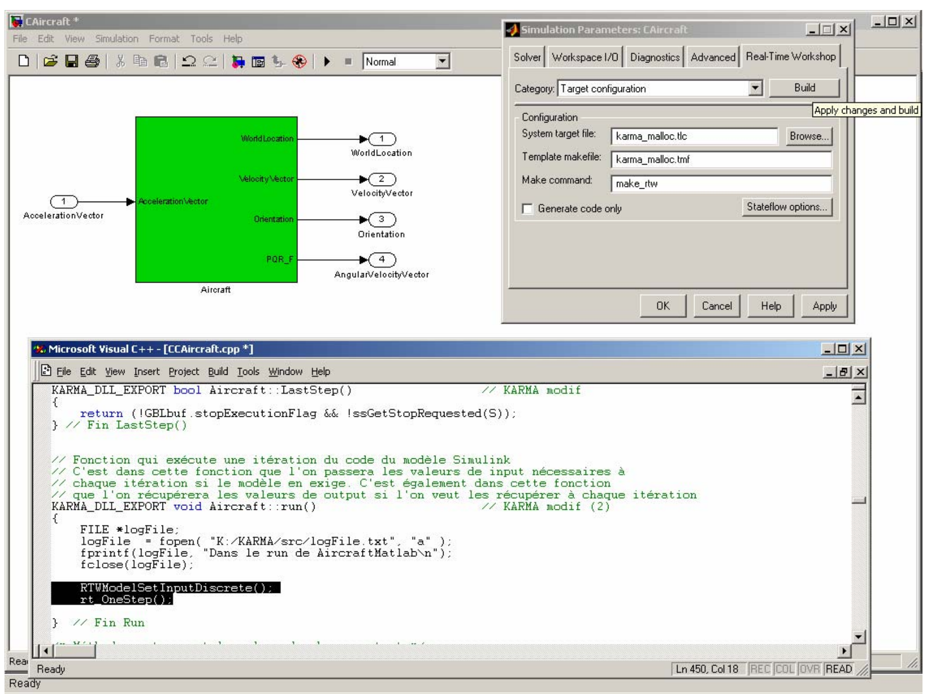

Figure 5h: Step 4c – Generating the DLL Using RTW®, TLC® Custom Script and Makefile.

Figure 5 cont'd: Screen Snapshots of the Tools Supporting the M&S Process.

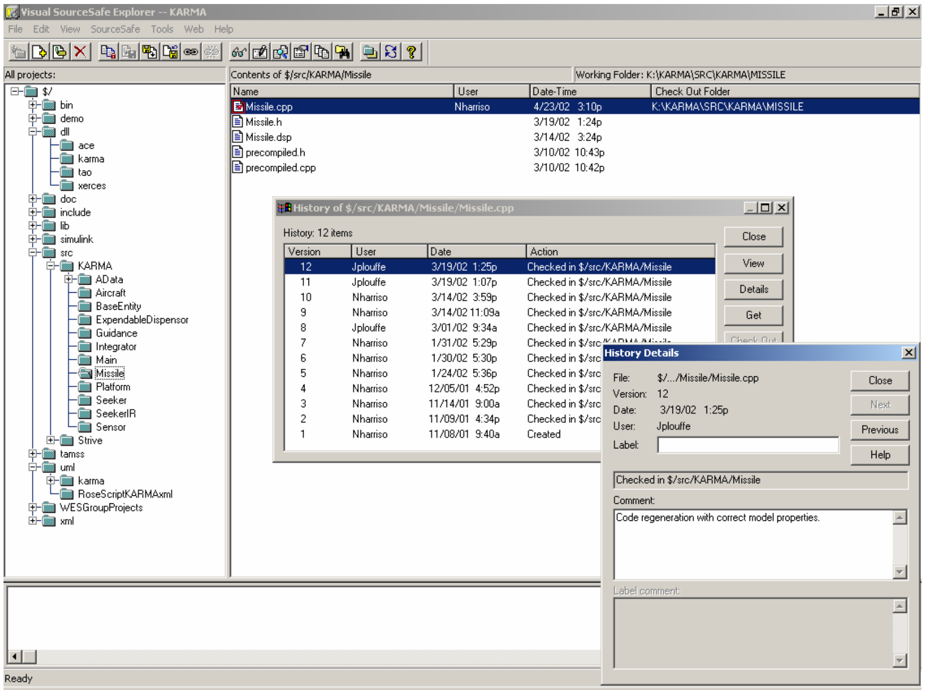

Figure 5i: Step 5 – Controlling the Versions and Sharing the Project Files with Sourcesafe®.

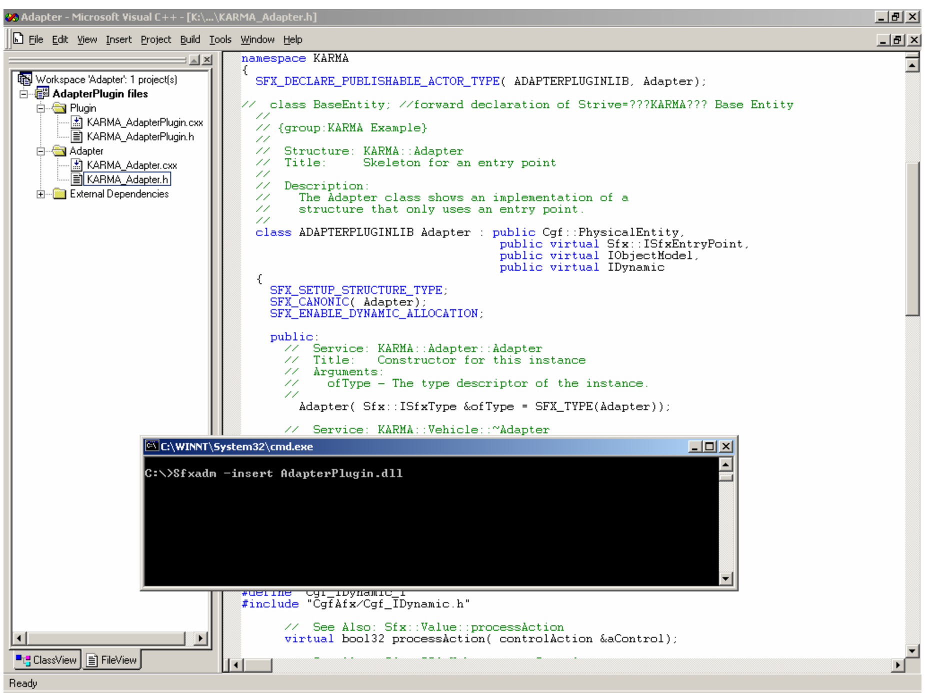

Figure 5j: Step 6a – Developing a STRIVE® Adapter in Microsoft Visual C++® and Inserting the Plug-In into the SFX.

Figure 5 cont'd: Screen Snapshots of the Tools Supporting the M&S Process.

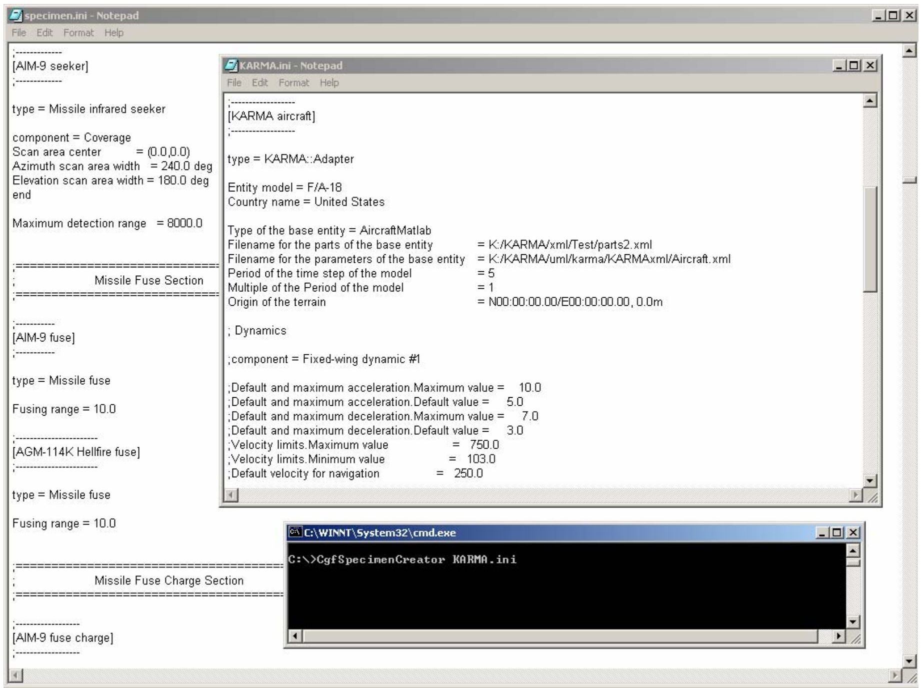

Figure 5k: Step 6b – Adapting the Data Files using a Custom STRIVE® specimen.ini File.

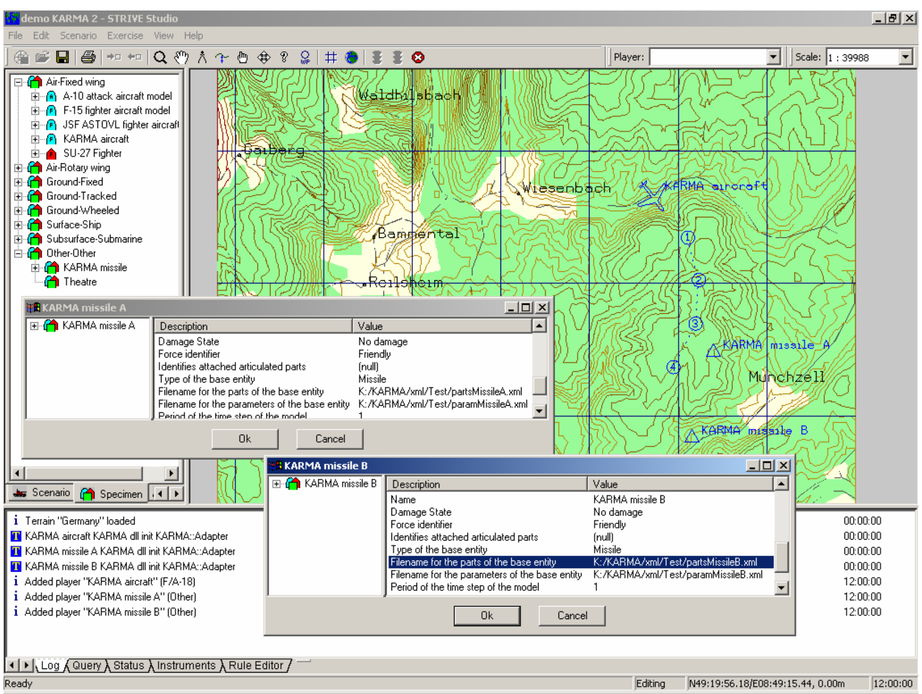

Figure 5l: Step 7 – Executing the Simulation in STRIVE®.

Figure 5 cont'd: Screen Snapshots of the Tools Supporting the M&S Process.

3.1 Simulation Modelling

Simulation modelling includes a series of tools to support the conceptual, scenario and physical modelling. Their link with each step of the proposed process is shown on Figure 4.

3.1.1 Conceptual Modelling

The process starts (Figure 4, Step 1 and Figure 5a) by agreeing on a conceptual model in UML using the Rational Rose® visual modelling tool [11]. It is a COTS product implementing the UML design standard and supporting OO and component-oriented conceptual modelling. The typical elements of the UML notation (use cases, class, sequence, component diagrams) are used to represent the conceptual model. The class attributes (parameters or initial conditions), methods, interaction and documentation are also systematically included in the UML class diagram.

3.1.2 Scenario Modelling

The second step of the proposed process (Figure 4, Step 2a and Figure 5b) consists in generating the XML parameter and initial condition files from the UML conceptual model using an automated functionality integrated into Rational Rose®. Practically, this is done in stereotyping, with the tag <<XML>>, the classes that require a parameter file. All class attributes that need to be configurable, either as a parameter or as an initial condition, are also tagged. Then, a custom script, integrated into the Rational Rose® tools menu, automatically generates default XML parameter files with the corresponding parameter names, data types, initial values and documentation. The practice of properly documenting the conceptual model and automatically generating the data insures the quality of the parameters data files.

Afterwards, the creation and the edition of the XML data files can also be done using a custom Java interface called the Studio (Figure 4, Step 2b and Figure 5c). This interface automatically adapts the Graphical User Interface (GUI) to the number and the name of the parameters defined into one model. It also dynamically represents the parameters according to their type. The data type entered by the user is validated and the minimum and maximum ranges permitted for each parameter are verified. Units and documentation are also displayed. The drag-and-drop capability of the GUI allows composing scenarios from entity models and entities from part models. The Xerces C++ and Java XML parsers [12] allow reusing the XML files at the scenario graphical modelling level, at the visual programming level and at the simulation framework level.

3.1.3 Physical Modelling

Based on the conceptual model, a C++ skeleton of the physical model can be automatically generated with Rational Rose® (Figure 4, Step 3a and Figure 5d). Moreover, Rational Rose® is integrated with the Microsoft Visual C++® development environment. The practice of systematically referring to the UML model to make any change on the skeleton and redo the automatic code generation ensures that the conceptual model always reflects the state of the implementation. It also improves the quality and the uniformity of the documentation and the code.

The modeller can then add the physical model directly in the reserved area of the C++ skeleton (Figure 4, Step 3b and Figure 5e) using Microsoft Visual C++® or any other appropriate development environment. At this stage, the modeller also has the possibility of wrapping a legacy model into the C++ skeleton of the class.

Alternatively, the modeller has the opportunity to use the MATLAB/SIMULINK® [13] visual programming tool for prototyping the physical model (Figure 4, Step 4a and Figure 5f). However, the SIMULINK® model should be consistent with the OO conceptual model to ensure the compliance between the SIMULINK® and the skeleton generated code.

When using MATLAB/SIMULINK®, the modeller shall associate the visual model with a XML data file (Figure 4, Step 4b and Figure 5g) to be consistent within the process. Custom tools were developed to use the XML data files with MATLAB/SIMULINK®: 1) XML files for SIMULINK® models are automatically generated using a m-file export program called MATLAB2XML; 2) parameters defined in XML can be imported in the MATLAB® workspace using the XML2MATLAB m-file program; and 3) the SIMULINK® blocks can be automatically associated with the XML Studio using an automatic configuration m-file.

If the modeller uses the MATLAB/SIMULINK® environment to develop the physical model, the proposed process allows to automatically generate a model component compiled as a Dynamic Link Library (DLL). The component is produced using the Real-Time Workshop® (RTW®) and the Target Language Compiler® (TLC®) COTS products (Figure 4, Step 4c and Figure 5h). RTW® is integrated within SIMULINK® and automatically generates portable and executable C code from the block model. Using the TLC®, included with RTW®, it is possible to customize the generated code and, for instance, wrap the produced C code into a C++ class compliant with the conceptual model. The interface of the resulting class is identical to the one automatically generated from the conceptual model with Rational Rose®. In addition, this code contains the calls to the MATLAB/SIMULINK® functions responsible for the mathematical modelling and the numerical integration. Finally, a custom makefile automatically compiles the generated code into a DLL to produce a stand-alone component.

3.2 Source Control

The modelling process produces model data for parameters, entity parts and scenarios in XML file format and model components in DLL file format. The different versions of these files are tracked using Microsoft Visual SourceSafe® COTS product (Figure 4, Step 5 and Figure 5i). SourceSafe® is integrated with the other modelling tools (Microsoft Visual C++®, Rational Rose® and MATLAB®) to optimize file management. Practically, it automates the sharing and the version control of the UML conceptual model, the C++ source code and the SIMULINK models.

3.3 Adapter

STRIVE® from CAE (Montreal, Canada) [14] is the simulation framework selected to demonstrate the process. It is an HLA-native framework that internally uses publish and subscribe as interaction mechanism. It implements distributed simulation using the Run-Time Infrastructure (RTI) [10] and supports an extended RPR-FOM. Its architecture is divided into two main elements: 1) a simulation framework, called SFX and 2) a Computer Generated Forces (CGF). It allows adding custom models that only use the SFX or use also the behaviours provided by the CGF.

Custom models are added into STRIVE® as plug-in components in DLL file format. To avoid coding the physical models using framework-dependent API, the proposed M&S process uses an adapter between the generic model DLLs and the STRIVE® SFX. The adapter can be initialized from a library template automatically installed by STRIVE® into Microsoft Visual C++® (Figure4, Step 6a and Figure 5j). In a single command line, the plug-in is inserted into the STRIVE® framework.

Similarly, the XML data files shall be adapted through a STRIVE® specimen initialization file (Figure 4, Step 6b and Figure 5k). This step represents the minimal effort required so that custom models could be recognized within the STRIVE® CGF.

3.4 Simulation Execution

Finally, the simulation is executed in STRIVE® (Figure 4, Step 7 and Figure 5l) to benefit from its built-in functionalities i.e., HLA compliance, distributed capabilities, visual scenario and doctrine creation tools, trajectory waypoints, 2D and 3D viewers, etc. Nevertheless, the custom model remains responsible for initializing dynamically its parameters from the XML files and the simulation results are always logged into XML files to maximize their portability.

4.0 THE INCUBATING PROJECT FOR THE M&S PROCESS DEVELOPMENT

This M&S process has been demonstrated in the context of an R&D project aiming at developing a weapon system engagement simulation environment. Typical requirements for such engagement simulations are, for example, to simulate a specific threat X, with the parameters Y, engaging a target Z that could counteract in specific ways. Implemented using a classical approach, this would have resulted in narrow simulation capabilities. With the use of the proposed M&S process, it has been demonstrated that various configurable subparts developed by several specialists can be connected and interchanged dynamically in the STRIVE® simulation framework.

The conceptual modelling allowed to devise and properly structure the main concepts of the simulation i.e., autonomous "Base Entities", composed of "Parts" equipments, are detecting each other within the "Environment" of the simulation "Theatre". Standardized terms from the RPR-FOM (such as "BaseEntity", "WorldLocation", "VelocityVector", etc.) were adopted to describe similar concepts. In order to meet the engagement simulation requirements, the base entity concept was specialized, for example, in "Aircraft" or "Weapon" and the part concept, in "Airframe", "Sensor" or "Propulsion". The conceptual model proved to be independent of the number and the assembly of instances.

The physical models of the parts used in the simulation were exported to DLL components from an existing MATLAB/SIMULINK® weapons library. All parameter, initial condition, base entity parts composition, scenario and log files were associated to XML files for universal use across the entire M&S process.

The execution of the simulation in STRIVE® allowed to play different scenarios by dynamically instantiating "Aircraft" instances composed of interchangeable parts, each with all configurable parameters. Through STRIVE®, the models also became HLA compliant.

The main objective of the incubating project was to establish a solid architecture and good teamwork practices such as information sharing and documentation. The experimentation of the process showed that such methodology and tools greatly improve the quality of the end product while easing further developments.

5.0 CONCLUSION

This paper proposed an automated iterative process, supported by a suite of software engineering tools and best practices, to guide modellers in the development of reusable and interoperable models. The application of this process brought to light the following advantages:

- the reusability of component models independent of any simulation framework;
- the interoperability improvement from an agreement at the conceptual level;
- the modularity of the models XML data and DLL components;
- the extensibility of the conceptual model and the simulation framework;
- the portability of the simulation data in XML format; and
- the quality and consistency of the outcome due to many automated steps.

On the other hand, the application of the process also showed some noticeable disadvantages like:

- the maintenance of custom tools developed to support the process;
- the uncertainty of being at the mercy of COTS tools providers;
- the significant integration work requiring specific skills;
- the learning curve of the modellers for the conceptual modelling; and
- the rigorous information (database) management required.

Through the experience of the incubating project, the following lessons were learned:

- despite the availability of tools and guidelines, no successful and cost-effective M&S could be achieved without a major change of mind about teamwork in the defence R&D community;
- transparent and efficient information sharing and appropriate communication and documentation must be established within the team;
- reusability and interoperability only occurs with an agreement at the conceptual model level;
- modellers must be left to do what they are the best at, the mathematical modelling of physical behaviours, while conforming to a rigorous method to maximize reusability and interoperability;
- modellers shall be properly educated on subjects such as the UML and the object-oriented paradigm – it is believed that these initial investments would lead to long-term payoff; and
- someone must be responsible for the integration in order to maximize the process efficiency.

Finally, the proposed M&S process only fosters model reusability and interoperability in providing guidelines to modeller teams. However, the object-oriented paradigm does not guarantee reusability and interoperability of the concepts. In order to achieve these requirements to a higher level, some constraints on the abstraction of entities, properties and interactions must be imposed [15].

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Asymmetric Threats Modeling and Application of LINGO Language

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The latest investigations in war gaming area are focused on new approaches to asymmetric threat modeling, analysis and prediction. Contemporary developments in game theory provide a flexible and powerful framework to model adversarial motivation and to generate credible asymmetric strategies for improved automation of behaviors in simulations and to support operations analysis and planning.

In most decision making situations the profits and losses are determined not only our decisions, but by the outside forces. The standard terminology applied to the problem to be considered is the game theory, especially through the features of optimization modeling with programming languages (LINGO [1]).

ASYMMETRIC THREATS

The notion, "asymmetric", as applied to asymmetric threat or asymmetric warfare has several meanings. Fundamentally, asymmetry upsets the offensive/defensive equilibrium to the perpetrator's perceived advantage by exploiting defense vulnerabilities or offense restraints with unconventional methods. An asymmetric attack is much less expensive to conduct than it is to defend against. Conversely, it is more difficult (expensive) to perceive an asymmetric defense tactic than it is to set one up.

"In an age when national decision making and commitment is driven more by public opinion than by policy principles and leadership we are particularly vulnerable to enemy information operations (IO) and propaganda which are generally considered to be tools in the asymmetric war chest"[2]. In consequence, modern asymmetric conflict tends to simultaneously expand the dimension of the conflict and merge decisions and actions conventionally separated into strategic, operational and tactical categories. The acquisition, operation and maintenance of the Command, Control, Communications, Computers, and Intelligence (C4I) infrastructure open yet another possibility for asymmetric attack by embedding or integrating commercial off the shelf (COTS) technology.

Asymmetric targeting is yet another dimension. Terrorism often intentionally strikes civilian or other non-combatant targets of opportunity, for the purpose of creating panic and shaking confidence in the competence of the authority or damaging the social stability and welfare.

The main feature of the asymmetric threats is the use of the scanty (inadequate) position advantages. Usually there are actions based on the unconventional ways and means, i.e. they don't oppose a force to the

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exceeding force in condition of an untraditional conflict. Such kinds of conflicts are terrorist acts and guerrilla warfare in which the goal is not to win, but to obstruct the powerful adversary to win, i.e. to avoid the loss.

Obviously, the answer does not comprise in military force engagements alone. Wargames are used for both training and analysis as well as in mission planning and rehearsal. The purpose is to synthesize sophisticated and agile C2 decision-making models for wargaming the asymmetric environment.

WAR GAMING

Contemporary strategy and doctrine are based on the joint and coalition operations. Operational wargames typically consist of multi-echelon (blue) participants as main forces, enemy (red), control staff white), and a number of neutral, friendly and coalition teams. Depending on the purposes – training, analysis, rehearsal, etc. – and size, and resolution of the wargame the infrastructure may be involved as well.

Virtual simulations are used in training and exercise wargames to stimulate the C2 equipment of trainees actually in the field, significantly augmenting the training environment with synthetic red or blue forces as needed. The need for valid and realistic simulated component behaviour has long required labor intensive scenario development and setup and, depending on scope, a sizable support team to steer or correct simulation behaviours that have gone off-track during the course of the run. High-resolution, multi-echelon constructive simulations are applied to create authentic and accurate representation of the environment and forces behaviour.

The war games need to incorporate behaviors and combined effects of both major and minor nation states as well as a host of non-state, non-governmental organizations, trans-national and international terrorist organizations operating in the asymmetric environment as well as corporate and criminal entities with significant business interests.

Recently the Operations Other Than War (Peace Making, Peace Keeping, Humanitarian Relief) are of special interest and they represent a natural match between game theory and the asymmetric environment. They create many challenges to the applied game theory in analysis and prediction.

GAME THEORY MODELS

The operation analysis and planning process is based on the ideas of game theory – the mathematical theory of decision-making in conflict situations. The game theory approaches give the opportunity to model the most important elements of the planning process – the analysis of opposing courses of actions, the behavior of the sides, payoffs and losses. These ideas assist to improve and refine the multi-player models with respect to the asymmetric threat.

Classification

There are many classes games, which are differentiated by various criteria – the players' number, number of steps, type of cost function, etc. (Figure 1).

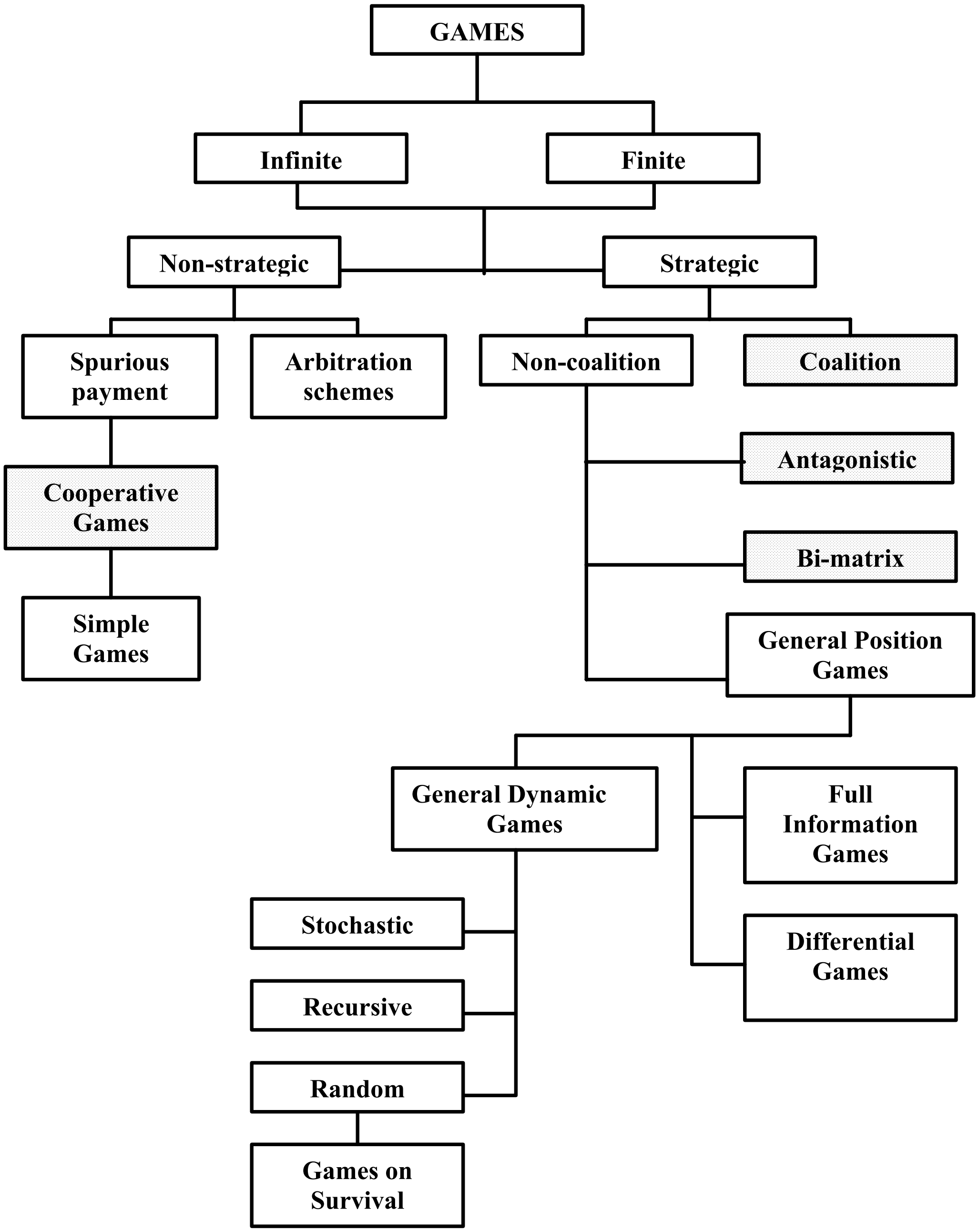

Figure 1

The real conflict can be modeled by the *finite antagonistic game* in case of the following conditions:

1) The conflict is determined by antagonistic interaction of two parties, each of which disposes only final number of possible (probable) actions.

2) The actions of the parties, undertake separately from each other, i.e. each of them has no the information on operation made by other party. The result of these actions is valued by a real number, which determines usefulness of the situation for one of the parties.

3) Each of the parties values both for itself, and for the opponent usefulness of any possible (probable) situation, which can develop as a result of their interaction.

4) The actions of the parties have not formal features. Thus the parties' actions can be treated as abstract homogeneous sets.

If the conflict corresponds to (1-4), defining one of the parties by the player *I* and another – player *II*, we can describe it by the antagonistic game [3]

$$\Gamma = < X, Y, H >, \qquad (1)$$

where – X is set of the pure strategies the player I, $X = \{ X_1, X_2 \dots X_m \}$;

Y is set of the pure strategies of the player II, $Y = \{ Y_1, Y_2 \dots Y_n \}$;

H is the function of usefulness of the player *I* (profit of the player *I*), which is determined for all couples of possible actions of the players.

The matrix is game-theoretic model of real conflicts adequate on conditions (1-4), i.e. we assign the finite antagonistic game as a matrix:

$$H = \|h_{ij}\|, \qquad h_{ij} = H(i,j), \qquad 1 \le i \le m\,,\ 1 \le j \le n; \qquad (2)$$

In order to find a stable optimal strategy it is necessary to solve the following equations:

$$E_1(X, y_j) \sum_{i=1}^{n} h_{ij} x_i = const(j = 1, \dots m); \qquad (3)$$

$$E_2(x_i, Y) \sum_{j=1}^{m} h_{ij} y_j = const(i = 1, \dots n);$$

$$\sum_{i=1}^{n} x_i = 1; \qquad (4)$$

$$\sum_{j=1}^{m} y_j = 1;$$

Thus the game payoff is:

$$E(X,Y) = \sum_{j=1}^{m} \sum_{i=1}^{n} h_{ij} x_i y_j \qquad (5)$$

The strategies $X^* \in X$ and $Y^* \in Y$ are optimal mixed strategies of player *I* and *II*, if the following expression is true:

$E\ (X,\ Y^*) \le E(X^*, Y^*) \le E(X^*, Y)$ in Cartesian product of the (X, Y).

The solution is in the following form:

$$\begin{aligned} &\left\| X^*, Y^*, v \right\| \\ &v = E(X^*, Y^*) \end{aligned} \qquad (6)$$

where v is the game cost.

It is possible to select real conflicts with the reasonably functioning parties and phenomenon, in which exists the undetermination caused by combination of objectively present circumstances – for example conflicts with a nature, or terrorist attack. The simulation of similar phenomena results in the special class of matrix games, namely “matrix games against the nature”. Special feature of these conflicts is the impossibility of physical implementation of mixed strategy that requires the random choice of pure strategy. The model is the matrix *H*:

$$H = \begin{pmatrix} p_1 & r_{12} + p_2 & \dots & r_{1n} + p_n \\ r_{21} + p_1 & p_2 & \dots & r_{2n} + p_n \\ \dots & \dots & \dots & \dots \\ r_{n1} + p_1 & r_{n2} + p_2 & \dots & p_n \end{pmatrix} \qquad (7)$$

where – $p_j > 0$ are the salvage charges (*j*-strategy of player II) and

$r_{ij} > 0$ are the losses of player II, caused by *i*-action of the “nature”(player I) in case of *j*-strategy of player II.

Two-player constant sum game (3) is suitable for modeling the antagonistic collisions. Ordinary linear programming can be used to solve this kind of games.

But there are many situations when the conflict is not strictly antagonistic. The appropriate simulation in these cases is non-constant sum games involving two or more players. There are some styles for creating non-constant sum games. If we restrict the examination to two players, then bi-matrix model extends the methods for two-player constant sum games to non-constant sum games.

Linear programming cannot be used to solve this game. However, closely related algorithms – linear complementary algorithms – are commonly applied. The cost matrix consists of two players’ matrixes:

$$A = \left\| a_{ij} \right\|, \quad a_{ij} = A(i,j), \qquad (8)$$

$$B = \left\| b_{ij} \right\|, \quad b_{ij} = B(i,j),$$

$$1 \le i \le m,\ 1 \le j \le n;$$

where a_{ij} and b_{ij} are respectively the profits of player *I* and *II* in situation *(i,j)*.

The probability player I to choose alternative i is X_i, respectively – for player II to choose alternative j is Yj. Because of this, the following constraints are correct:

$$X_i \geq 0; \qquad \sum_{i=1}^{n} X_i = 1; \tag{9}$$

$$Y_j \geq 0; \qquad \sum_{j=1}^{m} Y_j = 1;$$

In this case we are lead to the idea of a random or mixed strategy. For a bi-matrix game, it is difficult to define a solution that is simultaneously the optimum for both players. We can, however, to define an equilibrium stable set of strategies. A stable solution has the feature that, given choice X_{ij} of player I, player II is not motivated to change his probabilities Y_{ij}. Likewise, given Y_{ij}, player I is not motivated to change X_{ij}. Such a solution, where no player is motivated to unilaterally change his strategy, is sometimes also known as Nash equilibrium [4]. There may be bi-matrix games with several stable solutions. When the non-constant sum games have multiple or alternative stable solutions we should really look at all of them and take into account other considerations in addition to the loss matrix.

If the expected loss to player I is v_I and to player II – is v_{II}, therefore the solution of the game is:

$$\sum_{j=1}^{m} a_{ij} Y_i \geq v_I \ ; i = 1, \ldots n;$$

$$\sum_{i=1}^{n} b_{ij} X_j \geq v_{II} \ ; j = 1, \ldots m; \tag{10}$$

$$\sum_{i=1}^{n} X_i = 1;$$

$$\sum_{j=1}^{m} Y_j = 1;$$

In other cases the real situation supposes more participants in the conflict or mission. Then N-players game theory can be used in modeling the decision strategy. Usually, total benefit increase if the players cooperate. In these non-constant sum games the difficulty then becomes one of deciding how these additional benefits due to cooperation should be distributed among the players. The linear programming can provide some style in selecting an acceptable allocation of benefits. But this problem is not a subject of the present examination.

Applications

The core of the planning and decision making process model is based on the above-mentioned ideas from game theory. Game theory was chosen as the starting point because the theory addresses one of the central elements of the process, namely the analysis of opposing courses of action.

The planners on each side of the conflict have a separate (and generally different) payoff matrix, representing each planner's perception of the possible courses of action open to himself and his opponent, and the consequences of the interactions between them.

The essence of the deliberate planning model [5] is the analysis, by the planner, of this payoff matrix and the selection of a single course of action, that is, in some sense, the 'best' one to take, given the perceived options open to the enemy. The selection of a course of action is the command decision and is the key output of the deliberate planning process model.

There are several different ways of defining the 'best' course of action, depending on the criteria used to measure 'bestness'. Four such 'decision' criteria are the criterion of pessimism (maximin), the criterion of optimism (maximax), and the criterion of least regret and the criterion of rationality.

The application of LINGO-software gives the possibility to generate many various experiments and to obtain different results. That sort of research is very useful in the extraction of the experience from the historical data. Thus outline practical and rapid application of game theoretic approaches, applied to contemporary asymmetric conflicts.

Examples

In this examination were applied the game theoretic models proposed above to simulate some real situations [6]. Several tasks were solved based on the LINGO-software illustrating the usefulness of this commercial of the self (COTS) product for the military investigation purposes.

1) Side A organizes an air attack against an object, defended of the side B. There are three ways for side B to implement air defence of an object: Q_1 – the air defence equipment has a ring location; Q_2 – the air defence equipment is centralized in one sector; Q_3 – the air defence equipment is located as a semicircle. The effectiveness criterion is the probability of the achievement of the target by the aircrafts. The matrix of probabilities is given. Define the way to organize the attack of side A to defeat the object with greatest probability and the way to defence of the side B to protect the object from the attack.

B A	Q1	Q2	Q3
P1	0.8	0.2	0.5
P2	0.7	0.3	0.4
P3	0.5	0.6	0.3

```
MODEL:
MIN = LB;
a + b + c = 1;
-LB + 0.8*a + 0.2*b + 0.5*c <= 0;
-LB + 0.7*a + 0.3*b + 0.4*c <= 0;
-LB + 0.5*a + 0.6*b + 0.3*c <= 0;
END
LB      0.4000000
A       0.0000000
B       0.3333333
C       0.6666667
```

```
MODEL:
MAX = PG;
a + b + c = 1;
-PG + 0.8*a + 0.7*b + 0.5*c >= 0;
-PG + 0.2*a + 0.3*b + 0.6*c >= 0;
-PG + 0.5*a + 0.4*b + 0.3*c >= 0;
END
LB      0.4000000
A       0.5000000
B       0.0000000
C       0.5000000
```

$X^* = (0.5, 0, 0.5)$; $Y^* = (0, 0.33, 0.67)$; $v = 0.4$

2) Air Forces Staff has available supplies of three types of Chemical Air Bombs (CAB). During the use of chemical weapon the people are disposed into three types of shelters and when there is an alarm signal they can use only individual equipment for protection. The data for the human losses are given. Define the correlation of CAB in which will have the maximum damages (in %).

Type CAB	1	2	3
I	30	40	35
II	40	20	25
III	25	35	30

```
MODEL:
MAX = PG
GMA+GMB+GMC = 1;
-PG +30*GMA + 40*GMB + 25*GMC >= 0;
-PG +40*GMA + 20*GMB + 35*GMC >= 0
-PG +35*GMA + 25*GMB + 30*GMC >= 0;
END

PG      32.500000
GMA     0.7500000
GMB     0.2500000
GMC     0.0000000
```

X* = (0.75, 0.25, 0); v = 32.5(%)

3) The Division Staff plans to regroup the troops at a new region. They can realize this movement using three different routes. During the movement the enemy could attack only one of four discovered objects. The routes cross the traces of the radioactive pollution. The assessment of the probable human losses (in percents) is given. The troops must be allocated according to the routes in the way to sustain minimal losses (in %).

Objects Routes	1	2	3	4
1	15	14	40	35
2	20	18	30	24
3	40	35	25	20

```
MODEL:
MIN = PG;
GMA+GMB+GMC = 1;
-PG + 15*GMA + 20*GMB + 40*GMC <= 0;
-PG + 14*GMA + 18*GMB + 35*GMC <= 0;
-PG + 40*GMA + 30*GMB + 25*GMC <= 0;
-PG + 35*GMA + 24*GMB + 20*GMC <= 0;
END

PG             28.00000
GMA            0.0000000
GMB            0.6000000
GMC            0.4000000
```

X* = (0, 0.6, 0.4); v = 28(%)

4) The "reds" is given the task to capture the hill 5. The "reds" vanguard consists of three tank battalions with mobile infantry units. The "blues" have fortifications on the East Side of the hill and they defend the position through the mobile infantry and the air force units.

The "reds" can attack the object from three different directions – Northern, Southern and Eastern. The "reds" possible strategies are: *P1* – the attack from north, *P2* – the attack from South, and *P3* – the frontal attack.

The "blues" strategies are *Q1* –the air-force attack; *Q2* – shells; *Q3* – the attack with all weapons; *Q4* – attack with all weapons without the air force.

A	Q1	Q2	Q3	Q4
P1	0.3	0.8	0.7	0.65
P2	0.9	0.01	0.9	0.85
P3	0.6	0.6	0.15	0.25

B	Q1	Q2	Q3	Q4
P1	0.6	0.4	0.4	0.5
P2	0.2	0.85	0.2	0.35
P3	0.7	0.6	0.85	0.85

```
MODEL:
SETS:
OPTA/1..4/: PA, SLKA, NOTUA, COSA;
OPTB/1..3/: PB, SLKB, NOTUB, COSB;
BXA( OPTB, OPTA): C2A, C2B;
ENDSETS

DATA:
C2A =   0.3 0.8 0.7 0.65
        0.9 0.01 0.9 0.85
        0.6 0.6 0.15 0.25
C2B =   0.6 0.4 0.4 0.5
        0.2 0.85 0.2 0.35
        0.7 0.6 0.85 0.85
ENDDATA
```

```
CBSTA     0.5158273
CBSTB     0.5058824
PA( 1)    0.5294118
PA( 2)    0.4705882
PA( 3)    0.0000000
PA( 4)    0.0000000

PB( 1)    0.6402878
PB( 2)    0.3597122
PB( 3)    0.0000000
```

$X^* = (0.64, 0.36, 0)$; $Y^* = (0.53, 0.47, 0, 0)$; $v = 0.51$;

CONCLUSIONS

There are some particular areas in need of development if game theory is to be usefully applied as a tool in wargaming the asymmetric environment. There are some areas but progress in these would go a long way toward the realization of game theoretic war gaming.

(1) Synthesizing the game from the situation and historical data.

The analysts need a suitable tool for automatically enumerate relevant players, their options, and estimated payoffs. It is necessary to create and maintain a database, and to combine the expert knowledge.

(2) Finding and applying optimal strategies.

Multi player games model effectively conditions of contemporary conflicts – coalition creation, transnational organizations, etc. Variety of models corresponds to static or dynamic equilibrium. The strategy improvement bases on the use of expert knowledge of psychological factors.

(3) Directed modification of the game.

To update the games to similar situations has an important meaning for reusing the previous expert assessments on payoffs and previous solutions strategies.

(4) Use of modern modeling software.

Modeling languages give up powerful tools to model the conflict situations through the game theory application. The strategies are experimented and the solutions are proposed to planners and decision-makers.

The problem is whether suggested representation of war games generates emergent collective behavior that resembles realistic military environment. The assumption of complete information is the greatest impediment to the practical application of classic game theory. An asymmetric information game where players have incomplete information on either payoffs or options or both is much more typical of the real world situation. Preliminary results are encouraging and the next experience will present the validation of models. The research is still a work-in-progress.

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Enhancing Interoperability Through Standard Procedures for Recording and Communicating Information on V&V Planning, Implementation and Results

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ABSTRACT

Decision makers need confidence that the models and simulations they use are fit to support their decision making process, such that their decisions are useful to their specific project or program. It is entirely possible and even quite likely, that individual models and simulations or those expressly for federate use are already available somewhere in the world. Users of these models, simulations or federates need to appreciate the Validation and Verification (V&V) effort already applied to the product, and to understand the level of impact originally anticipated for the product use. This effort can be difficult to represent and understand when use and re-use are required, and as such, time and further effort can be wasted in duplicating and discussing the recorded information about a product of interest. In mitigation to this, a standard approach to recording and documenting V&V information is introduced. The impact level of the original use is also a useful data item in understanding the V&V effort likely to have been exercised on the product. This information is usually lost or not even recorded, and can leave subsequent users with some uncertainty about the suitability of the product for their purpose.

1.0 INTRODUCTION

The high importance that Modelling and Simulation (M&S) now affords National and International activities is becoming increasingly obvious. The implementation of M&S activities requires the formulation of higher levels of understanding and information transfer between NATO, the PfP, Industry and National organisations. Verification and Validation is an area where information, data and the understanding of them is of primary importance. Without the understanding, the information is nothing, and the goals of re-use and interoperability are not possible.

This paper is organised as follows; section two reviews the need for information, understanding and interoperability, section three introduces the area of recording verification and validation information. The new International Test & Operating Procedure (ITOP) is then described in section four as a method for standardising the information from the V&V-related M&S activities. The methodologies behind the ITOP are discussed in section five. A summary entitled ‘I don’t care what you do, as long as you record it consistently’ fills section six, and there after follows the conclusions and references.

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2.0 INFORMATION, UNDERSTANDING AND INTEROPERABILITY

Human discourse is based on the sharing of negotiated representations, and as such the management and interoperability of models and simulations is grounded in communication practice [1]. These statements were made concerning the risks of using M&S in the field of Agronomy – soil management and crop production. The risks detailed are of surprising relevance to the military domain – failure to appreciate structure and assumptions, and failure to appreciate the reliability of the data and its formulation [1] to mention just two. The offer of resolution and mitigation is stimulated by the question "What kind of representation (of information) would help?" [1].

As the complexity of constructed models, and we would claim, their predictive power, continues to increase, it has become clear that efficient and informed flow of information between modellers will become increasingly important and even vital [2]. Again this is a statement about the need for the management of information about models and simulations – this time from the field of Computational Neuroscience. Following some research into what neuro-biologists felt would be useful to them, again a surprisingly relevant set of requests was found [2]. Of most relevance to this particular paper were ones concerning the importance that models had references to the literature and information on the experimental techniques from which the used data was derived, and that simulation parameters should be retrievable for future simulation work [2]. This has direct implications for model use, re-use and interoperability in our field as well as the above.

Research into knowledge management models [3] has shown that competitive, commercial and potentially military advantage is increased through the interoperability and sharing of explicit knowledge. In particular the sharing of what is described as 'meta-knowledge' about reusability is described as critical for competitive advantage. This meta-knowledge, I would suggest, is the sort of information described previously in [1] and [2] – experimental techniques, simulation parameters, data formulation, model structure and probably most importantly, the assumptions.

3.0 RECORDING VERIFICATION AND VALIDATION INFORMATION

The concept of meta-knowledge introduced above [3] can be seen to represent the information that should be documented as part of a robust verification and validation procedure. Every little piece of V&V effort should be recorded and communicated to the accreditation authority, such that they may be convinced of the appropriateness and correctness of the model or simulation [4]. The lack of this type of information, alternatively described as the 'complex macro statements' has been quoted in a number of studies as reasons for the unsuccessful completion of studies based on models and simulations [5].

The lack of a standard method for recording the meta-knowledge or macro statements about the V&V of a model or simulations has been cited a number of times as the reason why so much valuable data is not available for use and exchange. In [6] this is made explicit when the authors state that 'A common format for V&V reports would be helpful because we could then accumulate this type of information'. They go on to note that we will not 'soon see a community standard for information items or formats'. Even within the NATO Modelling and Simulation Group, it has been recognised that a key area for standardisation is the communication, interaction and data exchange between people or systems [7].

4.0 THE NEW INTERNATIONAL TEST & OPERATING PROCEDURE ON VERIFICATION AND VALIDATION OF MODELS AND SIMULATIONS

Based on the implementation of the four-nation Memorandum of Understanding (FR, GE, UK, U.S.) on the mutual acceptance of test and evaluation, the International Test and Evaluation Steering Committee (ITESC) oversees the standardisation and documentation of test operating procedures produced by specific

Working Groups of Experts (WGE). The work of the committee is divided into eight management areas of particular concern in test and evaluation of military materiel, such as vehicles, weapons/ammunition, aviation, missiles communications /electronics, etc. In 1997 the new area of Modelling and Simulation (M&S) was introduced and a Management Committee (MC7) was set up because of the increasing importance of integrating M&S into other ITOP areas. The role of MC7 is to provide a co-ordinated approach to the subject among its WGE and the ITESC and to the WGE of the other management areas.

Working group 7.2 has been focussing on the use of verification and validation, its main activities have been:

- Preparing procedure and guidance documentation on the optimum use of V&V for other WGE;
- Preparing procedure and guidance information on how to transfer information from the V&V process to other nations;
- Promoting the use of defined V&V frameworks in T&E;
- Assisting other WGE in their use of V&V as regards their own simulations;
- Reviewing research developments into methods and tools useable in V&V and to facilitate their adoption where applicable;
- Build a reliable basis for future Accreditation of models.

This has resulted in the production of an ITOP document which can be utilised across the M&S and V&V community, if the community wants it.

5.0 CONCEPTS BEHIND THE V&V ITOP DOCUMENT

This ITOP applies to the V&V activities associated with models, data, and model use (or, more correctly its simulation) which are intended to support primarily defence applications, particularly where the mutual acceptance of results and information derived from the M&S is a key consideration for the reciprocal procurement of defence equipment. This section introduces key concepts that are used in the ITOP [8], these are a “V&V cases” concept, a “claim-argument-evidence” structure, and a “levels” concept for the classification of M&S-use impact and V&V activities.

To promote the avoidance of unnecessary re-analysis and evaluation, achieved V&V information from three elements (data, model, and simulation) shall be documented in three separate cases. This separation is done because it was felt that these were the information ‘blocks’ which were most likely to be transferred and re-used.

The concept of a claim argument evidence structure arose from the need to record the justification and reasoning behind important decisions. The precise way in which a claim for accreditation is divided into multiple lower claims has to be explicit and traceable – this is called the argument. The sub-claims may also be divided in to further claims by further argument until a hierarchy of claim and argument has been constructed. Eventually, the lower level claims should be able to be substantiated by a piece of evidence obtained from the V&V effort.

A levels concept assists in communication and understanding between parties in discussion. It also provides a convenient metric for comparison purposes ensuring that there is some consistency and standardisation between the entities of interest and some frame of reference[4]. In the new procedure there are two types of level of consequence – the impact level that the M&S is to be used for (e.g. a level of commercial, project, or human impact that would be experienced from the mis-use of the product); and the level of effort (and therefore cost) required to undertake verification and validation activities in order to generate a requisite amount of confidence that the model, data, or simulation correctly satisfies its purpose. There are obvious links between these two. A simulation used to predict kill/survivability rates would probably score a high impact level. As such it would likewise require a high level of V&V effort to provide evidence that it did behave appropriately.

6.0 I DON'T CARE WHAT YOU DO AS LONG AS YOU RECORD IT CONSISTENTLY

Documentation should be a normal part of modelling and simulation, for example some modern simulations do include their documentation on-line within the code [6]. This is a good situation as the information is likely to be current, controlled and will actually take up very little of a computer's storage capacity. A standardised or consistent format for this type of information electronic or hardcopy would be very helpful because the information would become easier to identify and could even be automatically read and accumulated [6].

The need for some generic document referred to as a 'logbook' has been identified as very useful [5], particularly for recording assumptions about the data, the model, the simulation run, or even just about the state of the real world. A document like this would have a number of potentially very important uses e.g.:

- An audit chain for decision making
- A structured walkthrough of the conceptual model [6]
- An assessment document for other applications
- An item of evidence to justify accreditation

The new ITOP aims to satisfy these requirements and uses by providing a template for such a document; a rationale for its use and some examples of how to apply the concepts discussed.

7.0 CONCLUSIONS

A new international standard for the recording of verification and validation effort has been constructed. It introduces several new concepts to this area including levels and the construction of reasoned arguments for accreditation. It is likely to have a dramatic impact on improving interoperability and communication between services, industry and nations. It will satisfy a requirement in the field of modelling and simulation for standardisation in this area.

Open distribution of this and any other ITOP is limited to FR/GE/UK/US Government agencies only. Requests from other countries should be referred to U.S. Army Developmental Test Command, ATTN: CSTE-DTC-TT-M Aberdeen Proving Ground, MD 21005-5055. In all cases the ITOP reference number and title should be quoted. Anyone can obtain a copy of an ITOP as long as there is no objection from the four countries.

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Combat Modeling by Using Simulation Components

"Today it is not the word "truth"
but the word "model" that
continually decorates the pages
of scientific journals."
Owen Gingerich (1982)

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ABSTRACT

Growing cost of operational trials and limited budgets make extensive live tests of military systems and frequent live exercises nearly impossible. Also defense planning dealing with extremely complex military system behaviors necessitates the utilization of innovative analysis tools. Simulation is one of the most employed tools for the military analyses, training and acquisition. Its increasing importance is now well-recognized in most of the armed forces and in NATO. Dramatic advances are being made in military simulation community, but these advances are associated mainly with computer technologies.

Modeling and simulation efforts are subject to some problems. First of all, building and using a simulation model is an expensive and laborious activity. It is difficult to design a model to efficiently and effectively support the appropriate analyses. Also, models are generally built in closed architectures and are difficult to adapt to the specifics of different, however related, analysis efforts. Turkish Navy has started a research project in order to minimize above deficiencies. This research effort concerns at first with the simulation model infrastructure and then the model itself. The research on simulation model infrastructure exploits the theory and methodology that will make it possible to design and construct reusable and flexible models.

The results of this study are going to be the development of a flexible, scalable and reusable tool that can be used for the construction of a library of Naval combat model components. The JAVA™ programming language has been chosen for implementation in order to take advantage of world-wide web. The purpose of Operations Research (OR) type of combat components is to provide a library of reusable software to speed development of OR applications and make them more reliable. The component architecture, which is in development phase, supports reuse, easy model configuration, interoperability, flexibility and scale changes in successive stages of analysis.

1. INTRODUCTION

The tasks that naval forces are required to perform have changed little over the decades. "However, existing instabilities in the international arena are being accentuated and new ones are appearing especially after the cold war era. Many conflicts arising from disputes over resources, ethnic and religious hatreds and drives for regional dominance can be expected. Thus, the future national security environment in which the naval forces will play a key part is likely to change dramatically "[Ref.1]. In addition to this fuzzy fast changing environment, technology is improving so rapidly as affecting weapon systems and spreading worldwide. Thus, a deterrent naval force will have to be alert for significant technological change and be ready to exploit new technologies.

What will be the impact of a new technology weapon system on naval vessels? This is one of the most central questions that a naval defense analyst must be asking to himself or herself. The growing cost of operational trials makes extensive live tests of new technology military systems nearly impossible. Analyses

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of such extremely complex system behaviors necessitate the utilization of innovative tools that are both flexible and reusable.

Simulation is one of the most employed tools for the military analyses. Ideally military simulation modeling should be quick, cheap, and yield precise answers. “However, many current models are large, monolithic and hard to understand” [Ref.2]. Models are generally built in closed architectures and are difficult to adapt to different scenarios. They often tend to be large. Addition to these, building and using a simulation model is an expensive, slow and cumbersome activity. However, military analysts concerned with the efficiency of simulation modeling, meaning that combination of correctness, flexibility and affordability that supports military decision-making.

For this main reason combat simulation modeling needs different ways of modeling approaches and techniques. Mainly these approaches or techniques should provide the strength of

- Modularity
- Scalability
- Reusability
- Network awareness
- Platform independent behavior,

to a Combat Simulation model.

Component Based simulation modeling is a good modeling solution for Combat Simulation efforts. It provides most of the properties mentioned above. Following sections explains the architecture of component-based modeling.

2. COMPONENT BASED MODELING

Component Based Modeling is in some sense an evolution of object-oriented thinking. However, it differs from object-oriented modeling in several ways and does not require an object-oriented programming language for implementation. In the following section, object-oriented and component based modeling are discussed in the simulation modeling point of view.

2.1. Objects vs. Components

First of all in Object Oriented Modeling it is difficult to couple objects loosely. However, simulation components are specifically designed to provide this property. In Object Oriented design, inheritance and overloading are the primary mechanisms for implementing polymorphism. On the other hand, in Component Based design common interfaces between components are established.

Object-oriented development is both a top down and a bottom up process. However, component-based design is a pure bottom up process. Component based design is fast comparing to object-oriented design, but requires the existence of an already build library of proven components.

In component-based design one important aspect is the degree of loose coupling between components. This property enables components to act without considering the outer world and this extends the flexibility and modularity.

Listener pattern is a software design pattern that enables the loosely coupling. It is the primary mechanism for components to interact. In this pattern components signal their state changes by broadcasting events to outside world and the objects that are interested about these changes receive these events. As explained in Ref.3 two types of components are involved with a listener pattern: the Listener component and the Event Source component. The “listening” component registers interest in another component’s events and waits for the other component to fire the event. When the event fires in the simulation component (that is, an event source component), it notifies all its registered listeners of the event. These events have no duration. The same component can serve as a Listener to some components and be an Event Source to other components. The Event that is fired should contain enough information for the Listener to be able to act without a callback to the Event Source. This no-callback property is a critical one for maximizing the looseness of the coupling between components. [Ref.3]

Component based design has been used a lot by computer hardware engineering and electrical engineering. A good example of a component system is the personal computer (PC). A PC has many parts (components) that communicate with each other. It is very easy to connect/disconnect or change components depending on need and use. Most importantly, all these components work together to form a complex system. Another example could be the electronic kits used in circuits. Simulation and Modeling community should try to benefit from components in the area of modeling as much as the other communities do.

A component is the basic element of component-based design. Although a satisfactory definition of component remains elusive, following section tries to explore a definition to simulation component.

2.2. What is a simulation component?

In his book "Beyond Objects: Components" Clemens Szyperski talks about components as follows "One thing can be stated with certainty: components are for composition. Nomen est omen. Composition enables prefabricated "things" to be reused by rearranging them in every new composites. Beyond that trivial observation, much is unclear." This sentence gives a sense of components even with no definition. [Ref.4]

According to OMG (Object Modeling Group) Modeling Language Specification "A component is a physical, replaceable part of a system that packages implementation and provides the realization of a set of interfaces."

Bertrand Meyer in his on-line article "What to Compose (Jan 2000)" gives the seven criteria for composites. According to these criteria, components;

- Maybe used by other elements (clients)
- Maybe used by clients without the intervention of components developers
- Includes a specification of all dependencies (hardware and software platform, versions, other components)
- Includes a precise specification of the functionality it offers.
- Is usable on the sole basis of that specification
- Is composable with other components
- Can be integrated into a system quickly and smoothly

Pidd [Ref.5] also makes a brief definition of a software component for discrete simulation and indicates the following criteria: Component's functionality should be entirely defined, all communication with any other components should be through a fully defined interface that is wholly unambiguous.

Arnold Buss in his paper "Component Based Simulation Modeling" defines component as a monolithic programming entity whose external interface consists only of property accessor/mutator methods, of action methods, and event handler methods [Ref.3]. This definition seems more specific than the others and focuses more on implementation. In this definition, *Property accessor/mutator* methods are small methods whose only purpose is to enable reading/writing a single property. Commonly used synonyms are "setters" and "getters" for these methods. An *event handler method* is a method that supports the Listener Pattern discussed above. Its signature is always the event of interest. An *action* method changes the state of the component in ways that are typically more complicated than simply setting the value of a property.

After all these definitions, a more general definition attempt could be as follows "A software component is an executable monolithic object designed to be easily replaceable as a unit in the context of system".

As seen in above definition attempt components are expected to be monolithic. However the term monolithic has a negative impact since it has been used to define legacy systems, which are too inflexible. A monolithic system is resistant to easy modification and is difficult to extend. Therefore, it is highly desirable for components since monolithic behavior prevents extension and represents solid structure and robustness.

Following properties are appeared to be the important properties of components. A software component;

- Should be able to work stand alone as separate entity,
- Should communicate with other components by passing messages,
- Should be able to provide data to each other,
- Must be composable,
- Must be loosely coupled,
- Should be simple,
- Must be of high quality,
- Should have a good documentation.

3. TURKISH NAVY AIR DEFENSE MODEL: AN EXAMPLE FOR COMPONENT-BASED SIMULATION

3.1. Architecture

As an operations analyst, one knows that effective analysis requires the simulation models to have flexibility, modularity, scalability and reusability. Another important feature is that the model should be independent of platform. In order to have such a model for Turkish Navy Air Defense analysis purposes component based simulation modeling approach has been chosen. JAVA programming language has been chosen for the implementation. A fundamental reason for selecting JAVA is the web technology. Web technology has the potential to significantly alter the ways in which simulation models are developed, documented, analyzed and executed. And Java programming language and its applications have substantially extended many capabilities for network based simulations. Pidd and Cassel [Ref.6, 7] also suggest the use of Java language for networked and web based simulation development.

Component architecture is developed by using the core structure, which is introduced in [Ref. 8]. As seen in figure 1, the combat component has a standardized way of sending or receiving messages from other combat components and processing these messages. This send/receive process is conducted by four connectors (pins). Two of these pins deal with incoming/outgoing events and the other two deals with incoming/outgoing properties. The following is the list of these pins and their duties,

Property user: The *property user* is the part of the combat component that deals with incoming properties.

Property source: *The property source* is the part of the combat component that deals with outgoing properties.

Event listener: *The event listener* is the part of the combat component that deals with incoming events.

Event source: *The event source* is the part of the combat component that deals with outgoing events.

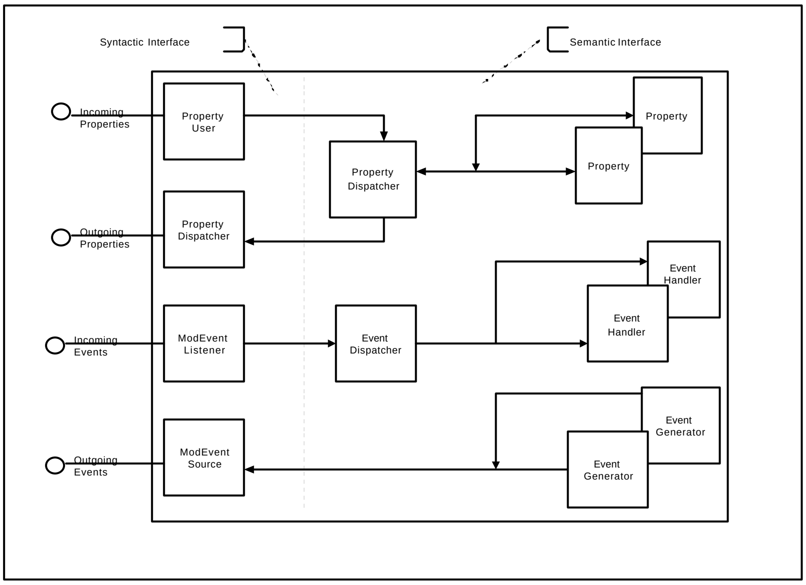

Figure 1. Basic Structure of Combat Component [Ref.8]

Definitions of the *event* and *property* will make the structure of the combat *component* more clearly to the reader. If a combat *component* wants to inform other components about a new change in its status, it will generate a message to all listener components without caring how the listeners react to that message. The content of this message is defined in the *event object* transmitted. This object is called an *event.* A *component* can generate and listen to *events*. A combat *component* is limited (monolith) in what it can do. Sometimes another component may tell a combat *component* what action to take or it may obtain some information from it. This action is implemented by using properties. A *property* is a piece of data that a component has, uses or can provide.

The combat components give us opportunity of building a library of combat components for fast and reliable modeling.

Another important structure of the component-based modeling is combat containers (Figure 2). A combat container is also a combat component that contains some other components and containers inside. Actual examples for Combat Containers are a plane, a ship, a guided missile, a tank etc. A combat container is the parent of all components it contains. This parent-child relation becomes important when composing complex systems. A modeler should only put the components that are created earlier into a container and do not think about their interaction inside the container. Two important properties of a container are its type and its side. Side is defined by a color code according to NATO Military Standards.

Discrete event simulation has been used [Ref.9, 10] for the scheduling purposes since it provides a flexible and descriptive modeling methodology, which is very convenient for our modeling purposes.

For geographical positioning purposes and visualization, Java based Geographical Information System (GIS) has been used. In order to maintain the flexibility the interaction between combat components and GIS has been designed in Model-View-Controller concept. In our case the Model is the Combat-Container library and it is the main body of the simulation. Since the model is made up of components and containers explaining these building blocks will reveal the simulation itself.

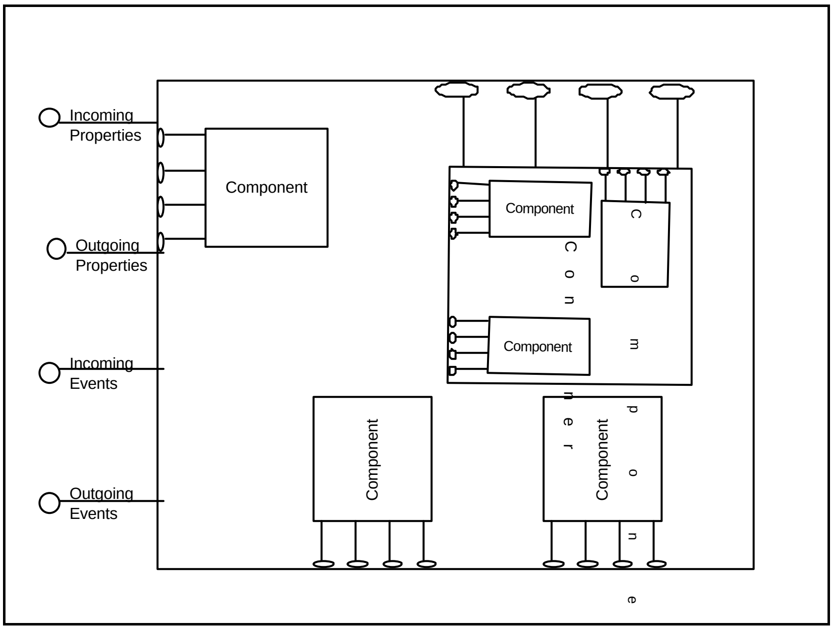

Figure 2. Structure of Combat Containers

The View is the GIS tool and it is composed of layers. For instance Digital Elevation Data (DTED) is a layer on the map. The Model interacts with View by way of a discrete event simulation layer and therefore it can reach GIS data easily. One of the reasons of this interaction is that a component, like active sensor, may need to calculate its Line Of Sight (LOS) by using one of the LOS algorithms existing in the literature all of which need terrain data.

The Controller is the scenario definition file for the simulation. Initial positions and parameter values of combat components are the some of the contents of the controller.

Following section provides structural information on Components and Containers of Turkish Navy Air Defense Model.

3.2. Components and Containers

This section mainly focuses on implementation rather than architecture. Three types of containers are created. These are Defender, Attacker and Defended Target. As discussed in previous sections a container is actually a combat component which can contain some other components. The component structure of the model is shown in figure3.

As seen in figure, all of the containers contain a common component named the mover component. Main functionality of the mover component is to keep track of the container's position according to its moving scheme. In our application the scheme is linear. It means that when a mover starts moving it proceeds with constant velocity and steady direction. Even though this is not realistic most of the time, this level of detail is accepted for our purposes. Future work consists of making the movement more realistic namely nonlinear. Perhaps in real life, a combat object usually moves nonlinearly which it can roll, yaw, pitch and accelerate.

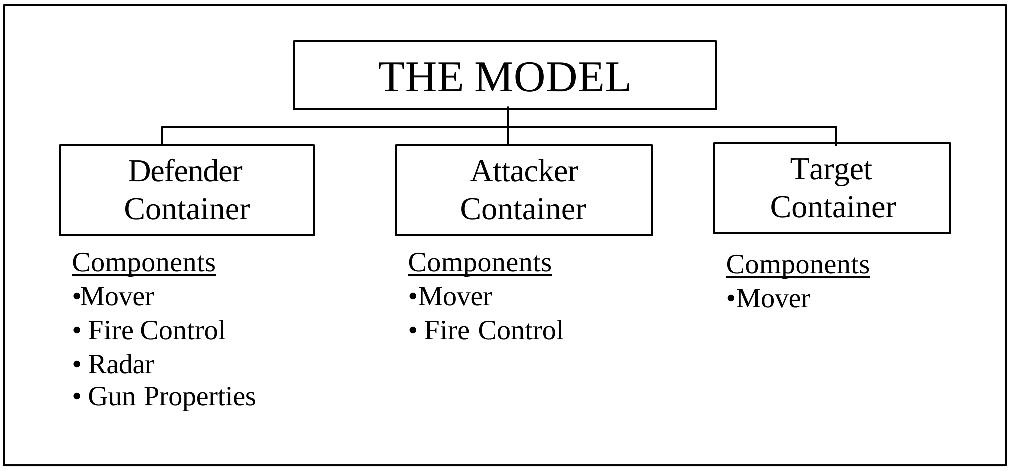

Figure 3. The Component Structure of the Model

The mover component is a property source and an event source. It has the necessary properties to keep location and velocity information. This will be the same for fixed components. In this case the mover component functions as a location marker. The mover component also fires necessary events in order to inform (notify) other components about position and state of the velocity changes. As an example, when a mover reaches to its given destination, it generates "At Location" event and notify listeners. Any event listener of the mover receives this message and reacts accordingly.

One of the most significant components in terms of functionality is the active sensor component. It is the implementation of radar in the model and a part of the defender container. Main function of it is to detect attackers in the surrounding area, such as cruise missiles or airplanes. Detection event is scheduled depending on line of sight of sensor, target's distance and detection probability of the sensor component.

In order to collect sample data from the simulation runs a listener component called " Stats Helper" is used. This component listens necessary events and keeps the necessary data about these events like time of the event.

Interaction between containers is handled by using small referee component, which evaluates the interaction between containers and gives a decision concerning this interaction. For example, interaction between radar and a target first investigated by a referee component which is created between these components and referee decides when the radar can see the target according to radar and target properties.

4. CONCLUSION

In this paper, we first presented a discussion on the proceedings of component based simulation and then made a formal definition for a simulation component. This is necessary to clarify our understanding on the terminology because of the difference between an object and a component may not be understood properly. Besides its theoretical side, we also presented an implementation that component based simulation concepts have been accepted. Remarkable point in our study is, as seen from the structure of the model, it is very easy to take out one of the components and put a different one in the model. This behavior provides analyst the necessary flexibility and speed. Thus, he/she can devote more time on analysis instead of trying to adjust an old model or building a new one.

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Acquisition par la simulation des systèmes futurs de combat aéroterrestre

(Simulation-Based Acquisition of the Future Air-Land Combat System)

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RESUME

De nouveaux concepts pour le combat aéroterrestre ont été définis, basés sur une approche système de systèmes, et qui se fondent sur des avancées technologiques récentes, comme les robots ou les capteurs miniaturisés. Afin d'explorer les différents concepts et d'engager les phases de conception des principaux systèmes concernés, la simulation apparaît comme un outil critique de décision. L'objectif de cet article est d'une part d'exposer l'approche par simulation pour l'acquisition de ces nouveaux systèmes de systèmes, d'autre part d'en démontrer la rentabilité économique.

ABSTRACT

New concepts for the future air-land combat have been defined, which are based on a system of systems approach and take advantage on the recent technological advances such as robotic vehicles and miniaturized sensors or systems. In order to explore the various concepts and to start the feasibility and definition phase of the main systems addressed, simulation proves to be a critical tool. We discuss in this paper our simulation-based approach and prove on the way its cost-effectiveness.

1.0 LA BULLE OPERATIONNELLE AEROTERRESTRE

1.1 Évolution du contexte : vers une logique capacitaire

Le principe de la BOA (bulle opérationnelle aéroterrestre) a été défini par la DGA (Délégation Générale pour l'Armement), en liaison étroite avec l'Armée de Terre. Ce projet fait suite à la nouvelle démarche de conception des futurs armements français entamée depuis 1997.

L'approche traditionnelle par armée ne permettait pas de garantir, dans la durée, toutes les cohérences (opérationnelle, technique, organisationnelle, calendaire) nécessaires à l'efficacité du dispositif militaire. Ainsi la prospective de défense s'appuie sur une approche par systèmes de forces reposant sur une logique capacitaire : au lieu de faire évoluer linéairement des systèmes d'armes en fonction des avancées technologiques, une réflexion d'ensemble a conduit à repenser l'outil de défense en termes de capacités opérationnelles, lesquelles ne font apparaître qu'en second lieu les concepts systèmes qui sont réalisés par

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différents systèmes d'armes, au sein de diverses organisations opérationnelles, dans le cadre de divers scenarii d'engagement.

Cette nouvelle logique ne construit donc pas l'outil de défense sur des matériels, des hommes et des doctrines préexistants, mais part au contraire d'une analyse des menaces et du besoin, pour en déduire des exigences fonctionnelles – les capacités, c'est-à-dire des systèmes de systèmes –, desquelles découlent les matériels, les hommes et les doctrines.

Comme on le verra ultérieurement, cette nouvelle démarche d'ingénierie du système de défense, qui se veut proactive et non plus au mieux réactive, nécessite aussi une nouvelle démarche d'acquisition.

1.2 Impact des conflits récents sur le combat aéroterrestre

Au vu des crises récentes (Liban, Koweït, Somalie, Bosnie, Kosovo…), plusieurs facteurs sont apparus déterminants pour les interventions aéroterrestres futures :

- l'amélioration de la protection des combattants (les armements ont une forte létalité et les crises se résolvent sous des contraintes de zéro mort ou tout au moins de pertes minimales, dont l'« acceptabilité » est essentiellement facteur de l'exploitation médiatique) ;
- le développement de la capacité de transport des combattants ;
- la multiplication des interventions en zones urbaines (cf. rapport du RTO group SAS30 « Urban Operations in the Year 2020 », diffusé en mai 2002) ;
- la variété des interventions (de la maîtrise de la violence à la coercition) ;
- la numérisation du champ de bataille (c'est une conséquence de l'omniprésence du numérique dans le civil et de l'intégration des nouvelles technologies de l'information dans les systèmes d'armes ; c'est aussi inévitable, suivant le principe de l'épée et de la cuirasse, les conflits asymétriques appelant l'utilisation de matériels de tous les jours, et requérant subséquemment leur neutralisation éventuelle).

Ainsi, les nouvelles caractéristiques des systèmes d'armes terrestres concernent :

- la capacité à combattre un adversaire au plus tôt, parfois au-delà de la vue directe ;
- la disponibilité de véhicules aisément transportables et fortement protégés ;
- une protection moins individuelle et plus globale (tant pour les hommes que pour les matériels) ;
- le développement d'armes neutralisant l'adversaire sans nécessairement le détruire ;
- la mise en place, sur des plates-formes automatisées (drones, robots terrestres) de certaines fonctions à risques importants pour l'homme (exemple : illumination laser de l'objectif afin de guider le tir) ;
- le développement des moyens de télécommunications (augmentation des débits de données en particulier), afin que ces différentes plates-formes puissent intervenir, en coopération, en temps réel (transmission d'images) ;
- la capacité à disposer d'une information complète sur la situation opérationnelle, en recoupant des informations provenant de capteurs terrestres (radars), aériens (avions, drones) ou spatiaux (satellites).

La BOA s'inscrit dans le système de forces « maîtrise du milieu aéroterrestre ». Constituée autour de véhicules blindés de masse réduite (18-25 tonnes), disposant de leur armement propre (exemples : canons, missiles), son efficacité reposera sur leur complémentarité de moyens qui fonctionneront en synergie.

Ainsi, par exemple, robots et drones de renseignement et de combat apporteront une capacité d'observation et d'intervention accrue, permettant la réponse la mieux adaptée à la menace détectée. Le principe essentiel est basé sur une mise en réseau des capteurs de tout type (exemples : imagerie visible ou infrarouge, radars) et des moyens d'intervention, afin que chacun bénéficie du partage de la situation tactique et en retour participe à son élaboration (compte-rendu de situation par exemple).

Le principe de la BOA repose donc sur l'action combinée d'un ensemble d'entités (hommes, véhicules, robots, drones) qui doivent pouvoir à la fois communiquer, observer, renseigner et agir. Le cycle « observation – décision – action » doit être extrêmement bref ; il requiert en particulier :

- des communications à débits importants,
- une architecture en réseau des capteurs,
- une fédération des capteurs de renseignement,
- une intégration forte du facteur humain dans le système d'information.

Des communications à débits importants : la nouvelle génération de moyens de communication doit être capable de transmettre jusqu'à 1 Mbits/s d'informations multimédia de qualité de service différente (voix, image, données, messages prioritaires, ordres temps réel) entre les capteurs, systèmes d'information et systèmes d'armes.

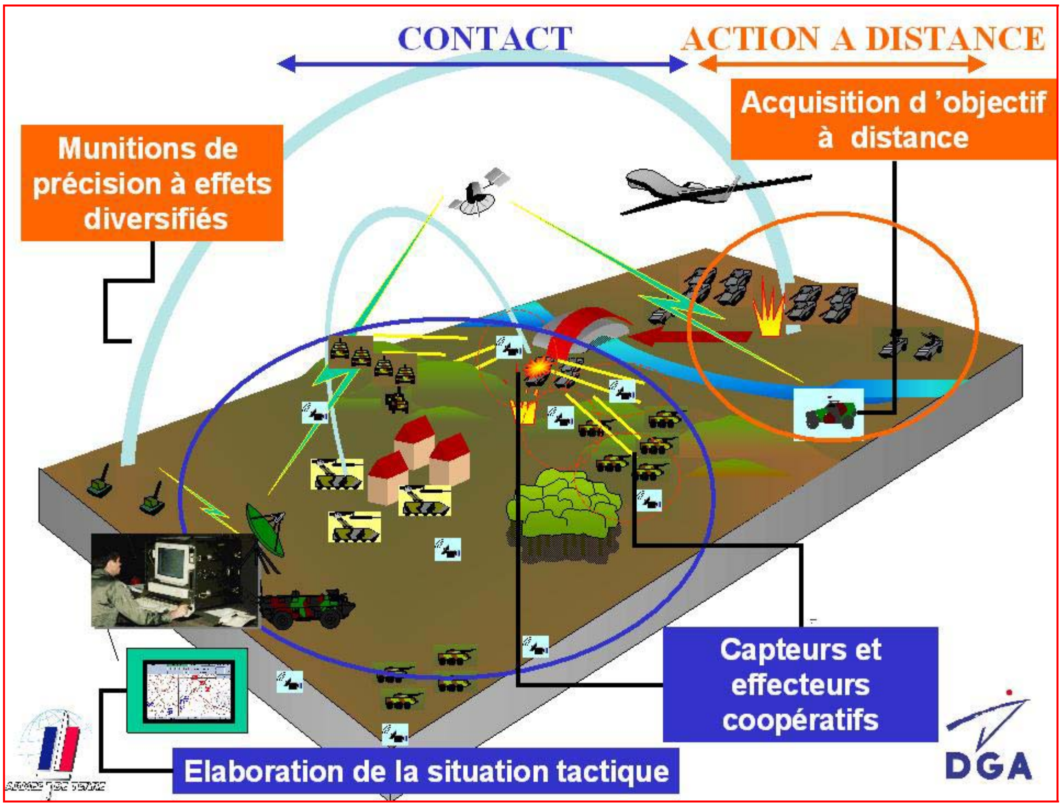
Comparables en termes de performances aux futurs radiocellulaires (MTS), ils devront de plus offrir des portées de 10 à 20 kilomètres, des délais de mise en œuvre et une résistance aux environnements électromagnétiques denses et agressifs compatibles avec des déploiements tactiques et une utilisation en zone urbaine.

Ces capacités permettront par exemple de récupérer les images vidéo acquises par les robots militaires terrestres pour les commander à distance plus efficacement.

Une architecture en réseau des capteurs : les réseaux sans fil mobiles tactiques répondent au concept de numérisation de l'espace de bataille et ils marquent le passage d'une gestion centralisée vers une organisation en réseau des armées (capteurs et systèmes d'armes). Les systèmes de capteurs mobiles et de systèmes d'armes, situés sur des plates-formes distinctes, seront reliés par un réseau de télécommunication à haut débit.

L'enjeu de ce type d'architecture est d'offrir une capacité plus rapide d'obtention, de traitement et de transfert d'information. Sur le plan technique, cette architecture de type réseau maillé doit s'adapter aux modifications de topologies en gérant l'initialisation du réseau, les problématiques de relais, la prise en compte de nouveaux entrants, la mobilité des entités connectées, la destruction d'un nœud…

Ces exigences ont été ou sont en cours de développement par le monde civil et l'adéquation des développements civils aux besoins militaires est à l'étude.



La fédération des capteurs de renseignement : dotée de capacités de recueil du renseignement performantes, l'Armée de Terre doit maintenant acquérir la capacité de couvrir l'ensemble du cycle de renseignement qui va de la demande jusqu'à la diffusion de ce renseignement. Dans la continuité du principe de mise en réseau des capteurs de tout type, ceci contribue à la fois à la conduite de la manœuvre des capteurs et à la diffusion des données sur l'adversaire, et cela à l'ensemble des acteurs et à un rythme compatible avec le tempo de la manœuvre.

En termes de fonctions à offrir, sont couvertes la planification du renseignement, l'optimisation de la conduite de la recherche et du recueil des données, l'exploitation et la diffusion du renseignement, et en final la contribution à l'élaboration de la situation tactique.

L'intégration forte du facteur humain dans le système d'information : les contraintes de réactivité pour l'opérateur nécessitent une automatisation maîtrisée des fonctions, d'où des problématiques de fusion de données, d'ergonomie et d'outils d'aide à la décision. On envisage par exemple de reconstituer un environnement à 3 dimensions à partir de capteurs hétérogènes et de le présenter soit sur un écran standard soit en mode immersif (par exemple via des lunettes de réalité virtuelle). La visualisation de l'espace en 3 dimensions facilite non seulement l'analyse de la situation opérationnelle, mais également la prise de décision par l'opérateur.

L'aspect facteur humain avec de nouveaux modes de pilotage des systèmes d'information (gants sensitifs, voix, gestes…) offre de nouvelles possibilités pour alléger la tâche des opérateurs humains, mais complexifie du point de vue système les interfaces et les contraintes d'intégration.

Les équipages restreints au sein de la BOA devront savoir traiter un flux très dense d'informations et un grand nombre de tâches variées. Les outils d'aide à la décision serviront à dégager des règles d'automatisation des traitements, de fusion de données et de présentation de l'information décisionnelle (indicateurs d'alerte, gestion des conflits, analyse des capacités opérationnelles…).

1.3 De l'innovation technologique à une vision globale du champ de bataille

Outre ces aspects de mise en œuvre de systèmes autonomes, de moyens d'observation et de communication, il faut aussi aborder les aspects de protection, mobilité et puissance de feu. Ceci conduit à repenser le système blindé, tant au niveau de son architecture technologique que de ses conditions d'emploi.

Le concept système actuellement à l'étude est celui de l'EBRC (engin blindé à roues de contact). Il assurera en 2011 des missions de reconnaissance et de combat : il sera le premier système d'armes issu du concept de bulle opérationnelle aéroterrestre. Les blindés légers de la génération précédente (AMX 10 RC par exemple) ne pouvaient combattre que l'adversaire qu'ils voyaient (avec leur propre viseur) et ne possédaient que leur seul canon (105 mm). Par ailleurs ils bénéficiaient d'une protection résultat d'un compromis entre mobilité et masse d'un blindage.

En comparaison, l'EBRC recevra des informations transmises par des capteurs déportés (robots, drones), lui permettant ainsi de combattre l'adversaire au plus tôt (au-delà de la vue directe) avec des moyens variés (canon, missile, éventuellement armes à énergie dirigée). Sa protection balistique pourra être complétée par des moyens de protection réactives, capables de détruire avant impact la munition adverse.

Afin de définir la répartition des fonctions entre véhicule blindé, drone ou robot, et de préciser le niveau technologique minimum à atteindre dans chacun des grands domaines techniques (protection, armes et munitions, mobilité, discrétion…) une approche système doit être conduite. Elle constitue une démarche indispensable et urgente pour pouvoir déterminer au plus tôt les compromis, financièrement raisonnables, techniquement réalisables et opérationnellement acceptables dans les délais impartis.

Si l'EBRC sert de moyen fédérateur à la constitution de la bulle de combat de contact BOA, celle-ci sera complétée par des modernisations des systèmes d'armes actuels (blindés actuellement en services, hélicoptères de combat, équipements de fantassins) et des mises en service de systèmes en cours de conception ou de réalisation (drones, systèmes d'information et de communication…) ainsi que d'autres nouveaux systèmes (robots…).

L'architecture globale de la BOA (vue comme un système de systèmes) doit donc intégrer certaines contraintes sur ces systèmes, et réciproquement les divers systèmes à mettre à hauteur ou à concevoir subissent des contraintes d'intégration horizontale et verticale.

Afin de relever l'ensemble de ces défis et de permettre à l'Armée de Terre d'assurer ses missions dans le contexte des années à venir, une démarche globale d'exploration des concepts au niveau système de systèmes, puis de conception, a été engagée. Elle repose essentiellement sur un processus de « simulation pour l'acquisition », étroitement intégré au processus d'ingénierie système de la BOA, seule solution pour garantir au juste coût la supériorité des futurs systèmes d'armes terrestres, qui ne dépend pas seulement de la performance individuelle des différentes solutions technologiques envisagées, mais surtout de leur association cohérente et réaliste.

2.0 INGENIERIE DES SYSTEMES ET SIMULATION POUR L'ACQUISITION

Avant de poursuivre, quelques définitions usuelles, extraites des référentiels normatifs largement utilisés au sein des équipes internationales de maîtrise d'ouvrage de systèmes, s'avèrent utiles, *système complexe*, *ingénierie de systèmes*, *modèle*, *simulation* :

- pour simplifier et au risque de déclencher des querelles d'école (entre structuralistes, fonctionnalistes, réductionnistes, comportementalistes…), disons qu'un ***système*** est un ensemble intégré d'éléments différents connectés et reliés entre eux, en vue de satisfaire un certain objectif [ISO-12207, EIA-632, CMMI] ;

- la ***complexité*** apparaît du fait tant de la nature (topologique et dynamique) de ces connexions et liaisons, que de la qualité intrinsèque des composantes ;
- l'***ingénierie système*** est une approche interdisciplinaire rendant possible la transformation d'un besoin en une solution système [CMMI], et permettant de dériver, faire évoluer et vérifier la solution système sur l'ensemble de son cycle de vie en vue de la satisfaction client [IEEE 1220-1994] ;
- la notion de ***modèle*** est assez claire pour tout le monde, à savoir une approximation, une représentation ou une idéalisation, de la structure, du comportement ou d'autres caractéristiques de la réalité, qu'il s'agisse d'un phénomène physique, d'un système ou d'un processus [IEEE 610.12-1990] ;
- par contre, la notion de ***simulation*** souffre de polysémie : elle recouvre en effet tant les activités de <u>*réalisation*</u> de modèles que celles de <u>*mise en œuvre*</u> de modèles en vue d'un objectif donné. Il apparaît que la simulation permet de reproduire les caractéristiques de l'environnement, des systèmes et de certains comportements. Outre ce côté *descriptif*, elle permet de *contrôler* des conditions et des situations, et donc d'*expérimenter* et d'*évaluer* des solutions. Évidemment cela se fait avec une souplesse, une sécurité et un niveau de coût que n'offrent pas les expérimentations réelles. La simulation apporte donc une aide précieuse entre autres sur le plan des doctrines d'emploi et de mise en œuvre des forces, et en parallèle sur le plan des équipements.

2.1 Adaptation des méthodes d'acquisition à l'évolution du contexte

L'ingénierie des systèmes complexes s'inscrit dans un contexte marqué par les grandes caractéristiques suivantes :

- les systèmes de Défense sont de plus en plus complexes, car intégrant davantage de composantes, hétérogènes et de durées de vie très disparates. De fréquentes rénovations suite à l'obsolescence des sous-systèmes, construits de plus en plus sur des technologies civiles, nécessitent de maîtriser les architectures a priori de systèmes dont on ne connaît pas les configurations de composants. La **réduction des risques** dans les différentes phases d'un programme d'armement (en amont de la faisabilité jusqu'à la mise en service, voire au retrait avec la prise en compte croissante de contraintes environnementales) devient alors un enjeu essentiel pour la **maîtrise des coûts** tout au long de la vie du programme ;
- la prise en compte de menaces nouvelles (post-guerre froide ou opérations autres que la guerre) nécessite une flexibilité et une réactivité importantes dans l'exploration des concepts de systèmes de Défense. Cette **évolutivité** de l'environnement et la nécessaire capacité du système à **s'adapter** à ces différentes évolutions contribuent à sa complexité ;
- l'évolution vers une logique capacitaire de l'outil de Défense oriente le processus d'acquisition vers la prise en compte de systèmes de systèmes. Ceci pose encore plus nettement les problématiques de l'**intégration**, de la **mise en cohérence** et de l'**interopérabilité** d'un système dans un système de niveau supérieur ;
- le contexte politique avec la réduction des budgets de Défense, la construction de l'Europe et l'internationalisation des forces de réaction aux crises requièrent une maîtrise des coûts d'acquisition, ainsi que des développements partagés entre partenaires. La **réutilisation** prend alors toute sa mesure.

Il est clair que dans le contexte concurrentiel mondial actuel, il est de plus en plus important de développer et de produire des systèmes robustes, fiables et de haute qualité, qui répondent de façon satisfaisante aux besoins de l'utilisateur final et soient économiques. Les ressources étant (malheureusement) nécessairement plus limitées que les désirs, il est plus important que jamais de disposer de pratiques efficaces tant dans la conception et le développement de nouveaux systèmes que dans la réingénierie des systèmes existants.

C'est cette prise en compte de la *totalité du cycle de vie des systèmes* (permettant d'intégrer dans la conception des systèmes futurs la rénovation et mise à hauteur des systèmes préexistants) qui nous fait considérer l'ingénierie système sur la totalité du cycle de vie, et non seulement sur la partie réservée à la définition (i.e. le passage formalisé du besoin aux exigences fonctionnelles puis aux spécifications techniques détaillées). Évidemment cela va nous conduire à devoir prendre en compte les problématiques de *partage* et *transfert de responsabilité entre acteurs successifs* au cours du cycle de vie (maîtrise d'ouvrage et maîtres d'œuvre), et leur conséquence logique en termes de *propriété intellectuelle*.

Même si nous ne développerons pas ces points dans les paragraphes suivants, leur prise en compte a été essentielle pendant la phase de contractualisation de l'outil de simulation pour l'acquisition dont il sera question ultérieurement. L'ambition affichée est de *disposer d'un référentiel partagé entre maîtres d'ouvrage et d'œuvre dans les étapes de définition et, à l'opposé, de responsabiliser le maître d'œuvre pour le développement et le maintien en service*.

L'ingénierie système comprend donc les efforts techniques afin de faire en sorte que le système soit conçu, construit et exploité pour réaliser son objectif de la façon la plus économique possible, en termes de performances, coûts, délais et risques.

Si l'on se réfère aux référentiels normatifs d'ingénierie système, on s'aperçoit qu'ils s'inscrivent dans une démarche générale d'ingénierie concourante et de développement intégré, et reposent sur une *vision complète du cycle de vie*, sur une *approche descendante* qui considère *le système dans son ensemble* en accordant une attention toute particulière à *l'expression initiale des exigences*, à la définition des *objectifs* et des *critères d'évaluation*, et sur une approche *d'équipe pluridisciplinaire*. Les principes suivants en sont les briques de base :

- appliquer une approche de conception hiérarchique descendante ;
- vérifier la conformité aux spécifications par une intégration et des essais ascendants ;
- mettre en œuvre l'ingénierie système suivant un développement du cycle de vie précis ;
- réaliser, dès le début, des plannings sur l'ensemble du cycle de vie en les basant sur les événements clés ;
- utiliser le travail d'équipe et les partenariats pluridisciplinaires ;
- réaliser des estimations et des mesures des progrès enregistrés à partir des performances ;
- contrôler l'évolution de la configuration ;
- réaliser des analyses technico-économiques sur les compromis envisagés ;
- identifier et résoudre les « contradictions d'ingénierie » ;
- utiliser les modèles et les outils assistés par ordinateur appropriés ;
- conserver une approche utilisateur.

Vérification, *validation* et *traçabilité* (des alternatives et des décisions) sont les étapes incontournables de tous les *rebouclages successifs*.

À l'inverse de l'approche analytique qui dissocie, partage, décompose, la logique systémique associe, rassemble, considère les éléments dans leur ensemble les uns vis-à-vis des autres, et dans leur rapport à l'ensemble. Dans des regroupements d'éléments, où la logique de groupe constitué prime sur celle de chaque élément qui le compose, ce qui est typiquement le cas des métasystèmes que nous considérons, un renversement de perspective s'impose. En effet, on part du constat que d'une part la complexité des systèmes et de leur agencement est telle que l'on n'arrive pas de manière séquentielle et cartésienne à les appréhender complètement, et que d'autre part le contexte environnemental a priori extérieur au(x) système(s) a une influence manifeste et non facilement prédictible sur les comportements locaux des éléments et le comportement global de l'agencement. Face à ce constat, l'acte de foi requis est un renversement de perspective qui consiste à accorder la prééminence aux liaisons entre éléments, donc à adopter un point de vue relationnel en lieu d'une décomposition élémentaire, et à se focaliser sur le contrôle de ces liaisons en vue de satisfaire l'objectif.

Un des atouts d'une démarche d'ingénierie système bien menée est de fournir les outils pour dépasser le simple stade de l'acte de foi ; en particulier, la simulation couplée étroitement à l'ingénierie système permet un rebouclage permanent au cours du cycle de vie, mettant en évidence d'une part ces rapports non immédiatement explicitables entre les liaisons incarnant les dépendances dynamiques et statiques et l'objectif, d'autre part les moyens de contrôle, éventuellement par tâtonnements et tentatives multiples suivant des paramétrages variés.

Aide à la décision et moyen de maîtriser la complexité, la simulation pour l'acquisition des systèmes devient alors incontournable.

2.2 La simulation pour l'acquisition : une vision cohérente de la vie du système

Réduction des coûts et délais d'acquisition sont les soucis majeurs des services de maîtrise d'ouvrage, car ils ont un impact immédiat sur le coût et la disponibilité des matériels. Leur maîtrise sur l'ensemble des phases du cycle de vie du système, ainsi que des éléments de niveau supérieur auxquels il s'intègre, est une condition sine qua non du déroulement nominal des programmes d'armement.

Reprenant la vie du système étape après étape, les apports principaux de la simulation se déclinent aux niveaux de :

- *la maîtrise du besoin :*
  - évaluation des concepts d'architecture globale,
  - analyse des compromis entre capacités opérationnelles, performances, coûts,
  - choix de l'architecture optimale du système,
- *la maîtrise des spécifications :*
  - démonstration de la faisabilité technique avant la réalisation,
  - détermination de l'organisation la plus adéquate pour le développement,
  - formulation de spécifications vérifiables,
- *la maîtrise de la réalisation :*
  - exploration des différentes options de fabrication pour optimiser le choix de la solution dans le respect des contraintes techniques de coûts et de délais,
- *la maîtrise des évolutions et l'intégration au niveau supérieur :*
  - assurance de la cohérence dans les diverses phases du cycle de vie du système,
  - garantie de réutilisation de partie ou globalité des composants et sous-systèmes au sein d'autres systèmes.

Les modèles et simulations développés lors des différentes phases sont certes différents, mais ils s'inscrivent dans une communauté, celle du système et plus généralement du métasystème. Ceci vaut pour la phase de préparation, avec les simulations souvent qualifiées de technico-opérationnelles, pour la phase de conception, où les simulations ont un caractère technico-fonctionnel, pour la phase de réalisation, où les simulations sont cette fois a priori de responsabilité du maître d'œuvre et étudient les alternatives techniques de développement et prototypent la fabrication, pour la phase d'utilisation, où les simulations ont trait tant à l'entraînement qu'au soutien, et enfin pour le retrait de service, lequel met quelquefois en jeu des défis non négligeables en terme d'impact environnemental (pensons à la chute de la station orbitale Mir, ou au démontage des centrales nucléaires).

Ignorer cette communauté d'intérêts – et considérer donc une simulation comme un outil pratique mais ponctuel pour analyser un problème technique particulier sous différents angles d'approche – revient à tirer un trait sur une vision cohérente de la vie d'un système, et par là même est un obstacle à la réutilisation tant intra-système que inter-système. Avant de revenir sur ce point dans les analyses économiques à suivre, revenons sur ce qui vient d'être dit, et en particulier sur la communauté entre simulations technico-opérationnelles et techniques.

La frontière que beaucoup établissent entre simulations technico-opérationnelles et simulations techniques n'est, de notre point de vue, qu'une querelle de chapelles, visant à poser des impossibilités de principe pour tenter de défendre une spécificité qui leur est propre et devant justifier l'exception, en particulier vis-à-vis de l'intégration au sein d'équipes pluridisciplinaires et plus largement dans une vision globale de la vie du système avec partage des modèles et outils. En fait, dans une démarche de processus d'ingénierie système, il n'y a pas de place pour des frontières arbitraires et infranchissables ; c'est d'autant plus impensable pour un ensemble de systèmes qui sont à différents stades de leur cycle de vie !

L'argument fallacieux qui consiste à dire que, comme les modèles utilisés pour les différentes simulations et les diverses vues du système sont différents (car il faut simuler ni trop ni pas assez), il s'agit de métiers différents, est fondé sur une interprétation erronée de la notion de représentations diverses d'un même système : il présuppose en effet une hiérarchisation de type arborescente des représentations (respectivement technico-opérationnelles et techniques), où l'on va du plus simple au plus détaillé ; le problème évidemment posé est alors la détermination de la frontière entre niveaux de détail des modèles, afin de garantir une convergence (au sens d'une adéquation des résultats de simulation obtenus au réel). Ceci est manifestement difficile, voire impossible numériquement. Mais ce type de raisonnement est foncièrement biaisé et repose sur une conception analytique du système. Fidèle au renversement de perspective discuté précédemment, il convient de relier les différents niveaux de représentations par un mécanisme dit de « transformation naturelle » et non de « décomposition arborescente ». C'est d'ailleurs la notion mathématique s'imposant naturellement quand on adopte un point de vue relationnel : elle revient à être capable de définir des correspondances (des « morphismes ») entre composants de différentes représentations, sans exiger une inclusion entre niveaux, mais simplement en forçant la cohérence systématique des dépendances (ce principe de propagation fait alors remonter les structures locales jusqu'à l'architecture globale ; alors que dans la vision arborescente, la localité suffit). On n'est donc plus dans une logique où un système d'équations, que l'on considère comme représentant un « modèle plus fin », en remplace un autre de manière biunivoque, mais au contraire dans une logique de traçabilité des dépendances entre expressions du besoin, exigences fonctionnelles, implantation des fonctions sous forme d'ensembles de comportements, composants…

En fait, on s'aperçoit que la solution au paradoxe apparent vient là encore d'une nécessaire prise en compte de l'organisation relationnelle globale du métasystème !

2.3 Prémices d'une justification économique de la simulation pour l'acquisition

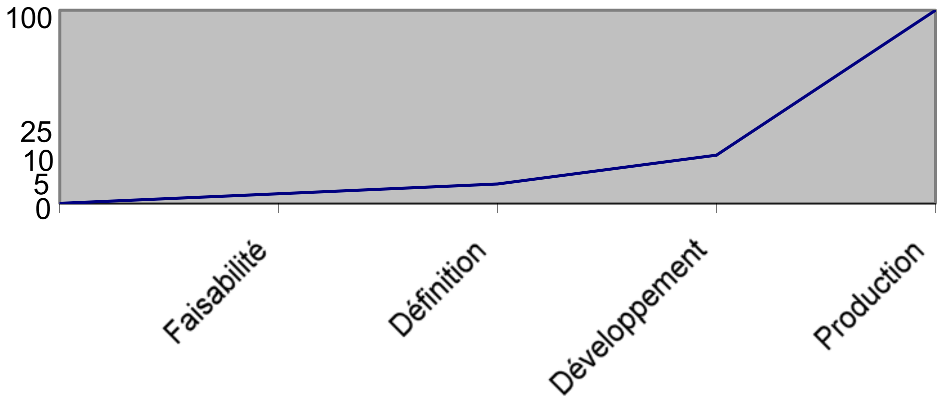
L'impact premier de la simulation pour l'acquisition au cours de l'ingénierie d'un système est *la marge de manœuvre en termes de coûts engagés à l'avance* par les décisions prises à chaque étape au cours du cycle de vie. En effet, la simulation permet d'embrasser un éventail plus large d'alternatives techniques, d'abord à un instant donné (donc au cours d'une phase particulière du cycle de vie), mais surtout sur une certaine durée (ce qui permet de mener en parallèle plusieurs tronçons alternatifs du cycle de vie, et de mesurer en aval de la vie du système l'impact, en termes de performances ou de coûts, d'une décision prise en amont).

C'est cette liberté de manœuvre accrue qu'il va falloir comparer au surcoût engendré par le développement et l'intégration concourante des simulations. Pour cela, nous allons d'une part estimer ce surcoût relativement au coût complet de l'acquisition (de la conception à la réalisation) « traditionnelle » du système. Il est à noter que nous ne comptabilisons pas la phase d'utilisation du système, c'est-à-dire son exploitation et son soutien : en effet, le cumul des coûts récurrents au vu de la durée de vie de plusieurs décennies des systèmes de défense fausserait complètement toute analyse (le Department of Defense aux Etats-Unis estime la répartition relative en pourcentage entre acquisition, exploitation et soutien à 28, 12 et 60). D'autre part, nous allons quantifier la marge de manœuvre obtenue par la simulation pour l'acquisition, en considérant le cas de surcoût d'acquisition dû par exemple à un imprévu ou une erreur de planification.

Il est à noter que la discussion informelle précédente conçoit la simulation comme un processus intégré au cycle de vie du système à acquérir, dans la mesure où c'est la dimension diachronique qui est mise en avant. En effet, l'utilisation ponctuelle de la simulation va entraîner des économies très relatives, par exemple pour éviter le recours à une maquette ou un prototype. Mais rien ne garantit dans ce cas que la simulation n'engendre pas un surcoût net, soit de par son développement, soit de par sa validation. En effet, si l'utilisation de la simulation a été ponctuelle, il y a peu de chance qu'il y ait une validation disponible au service de l'équipe d'acquisition, car cela présuppose des processus de traçabilité et de capitalisation, qui sont justement les prémices d'une démarche de simulation pour l'acquisition !

2.3.1 Calcul du surcoût dû à la simulation pour l'acquisition

Nous partons de la courbe classique, dite de Pareto, extraite de tout manuel d'acquisition de programmes ou de gestion de projet, et représentant l'évolution du cumul des coûts d'acquisition en fonction de l'étape correspondante du cycle de vie.

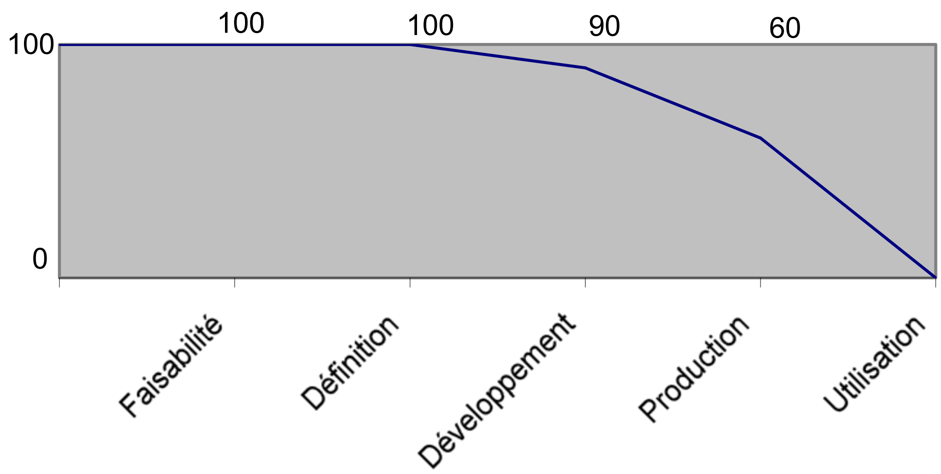


Evolution du cumul des coûts d'acquisition en pourcentage relatif du coût global d'acquisition.

Sur cette figure, les ordonnées sont données à titre indicatif et varient de quelques unités selon les sources (manuel d'instruction de conduite de programmes de la DGA, DoD aux Etats-Unis, données des groupes de travail « Software Engineering » de l'INCOSE).

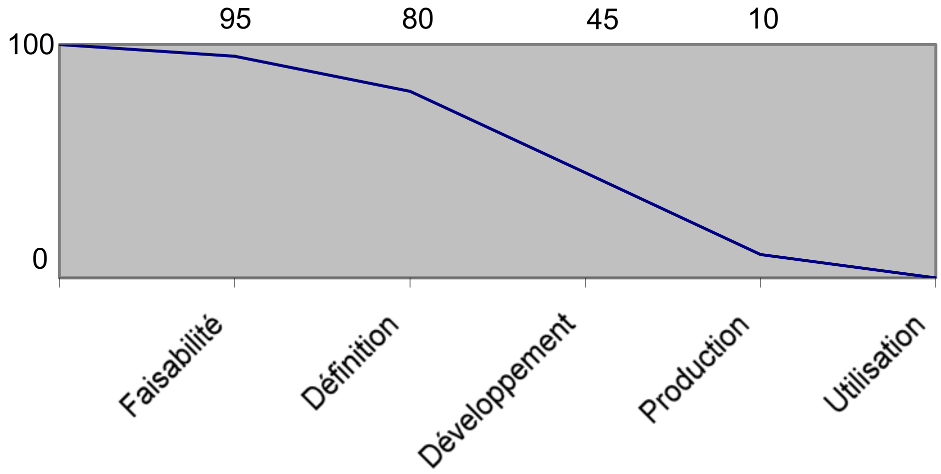
La part relative de la simulation au cours de l'acquisition est évidemment variable, selon qu'une démarche avec ou sans prototypage virtuel est adoptée, c'est-à-dire selon l'avancement de la philosophie simulation pour l'acquisition.

Dans le cas idéal d'une acquisition intégrant complètement cette philosophie, où le cycle de vie est déroulé virtuellement et successivement selon un mode en spirale avant d'aboutir au produit final, on obtient la courbe suivante tel que donnée dans le rapport du RTO group NMSG003 « M&S technology in support of SBA ».



Part relative de la simulation au cours du cycle de vie.

Dans une acquisition « traditionnelle », on observe plutôt une courbe en S du type suivant.



Part relative de la simulation au cours du cycle de vie.

Dans les deux cas, la simulation occupe une part majoritaire, voire quasi-exclusive pendant la phase de conception (faisabilité et définition). Par ailleurs, en première approximation, nous supposerons le coût de la simulation indépendant de la phase du cycle de vie, et uniquement dépendant du pourcentage occupé par les activités de simulation au cours de chaque phase. Cette hypothèse néglige donc certains coûts d'intégration logicielle horizontale (c'est-à-dire sur plusieurs phases du cycle de vie), ainsi que des coûts de validation des simulations. Les premiers contribuent en effet pour un ordre inférieur. Les seconds modifient légèrement les calculs présentés ici, sans en changer les conclusions. Mais leur prise en compte explicite ne saurait se faire sans une analyse plus complète du processus d'acquisition par la simulation, avec notamment les efforts de capitalisation en termes de vérification et validation, démarche rentrant aussi dans le cadre d'une analyse multiprojet du type de ce qui est développé dans la section suivante.

On obtient alors le coût relatif de la simulation pour une acquisition « traditionnelle » par la convolution des deux courbes, respectivement d'évolution des coûts relatifs et de part relative de simulation. Pour simplifier le calcul, nous faisons une approximation par interpolation barycentrique, ce qui revient à multiplier pour chaque étape le coût moyen (relatif au coût global d'acquisition) de l'étape par la part relative moyenne occupée par la simulation au cours de cette même étape :

- Coût relatif moyen en faisabilité : (0+5)/2 = 2,5
- Pourcentage moyen d'utilisation de la simulation en faisabilité : (100+95)/2 = 97,5
- Coût relatif moyen en définition : (5+10)/2 -5= 2,5
- Pourcentage moyen d'utilisation de la simulation en définition : (95+80)/2 = 87,5
- Coût relatif moyen en développement : (10+25)/2 -10= 7,5
- Pourcentage moyen d'utilisation de la simulation en développement : (80+45)/2 = 62,5
- Coût relatif moyen en production : (25+100)/2 -25= 37,5
- Pourcentage moyen d'utilisation de la simulation en production : (45+10)/2 = 27,5

Coût de la simulation dans une démarche d'acquisition « traditionnelle », en pourcentage du coût global d'acquisition : (2,5*97,5+2,5*87,5+7,5*62,5+37,5*27,5)/(100*100) = 19,6.

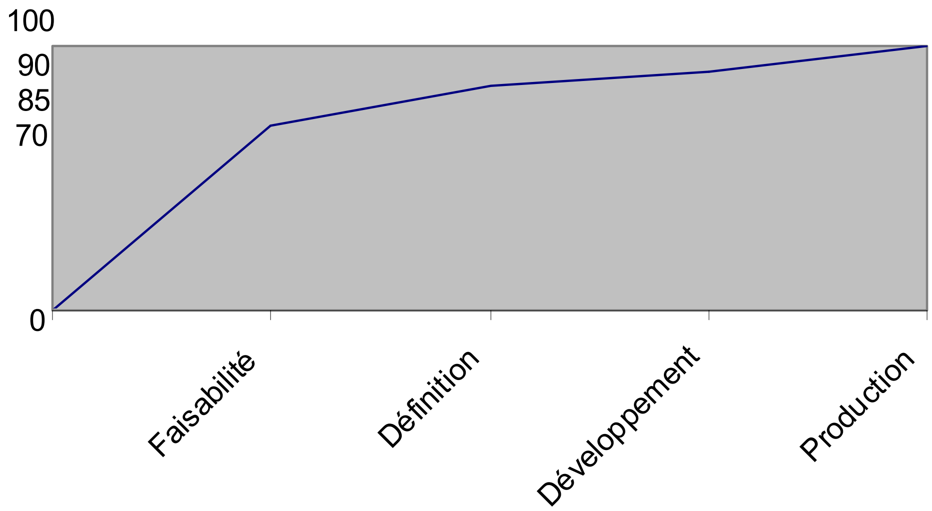
Pour une démarche de type simulation pour l'acquisition, on obtient en final : (2,5*100+2,5*100+7,5*95+37,5*75)/(100*100) = 40,2.

La différence de ces deux coûts donne le surcoût d'une démarche SBA.

Le surcoût de la simulation pour l'acquisition peut donc être estimé à environ 20,6 % du coût global d'acquisition.

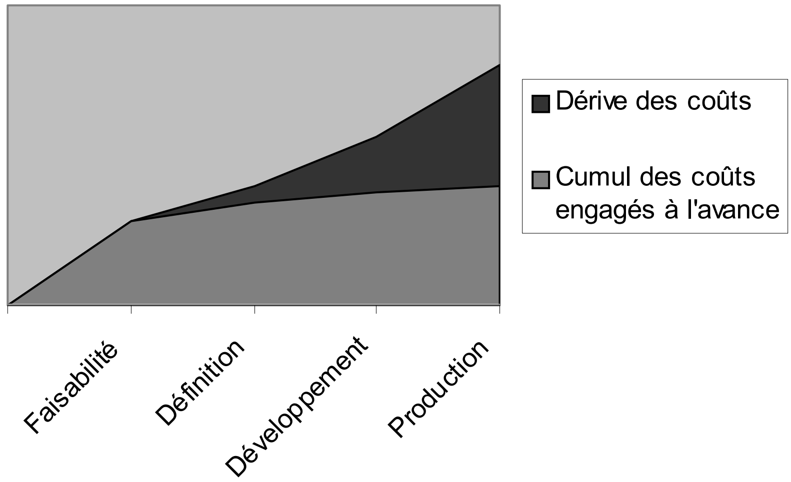
2.3.2 Surcoût engendré par un imprévu ou une erreur de planification

Nous partons de la courbe donnant les dépenses engagées à chaque instant par les décisions déjà prises. La courbe classique (avec les mêmes remarques que pour l'autre courbe de Pareto) est la suivante.



Cumul des coûts engagés à l'avance.

La courbe suivante définit la zone de dérive de coûts, en termes de surcoûts engagés par avance du fait d'une modification non prévue.



Une des conséquences de la simulation pour l'acquisition est de réduire les risques, en étudiant simultanément plusieurs alternatives et donc en prenant les décisions finales ultérieurement, c'est-à-dire en engageant moins tôt les coûts des phases ultérieures. Ceci a pour effet de décaler d'une part la courbe des coûts engagés par avance et a fortiori la zone de dérive des coûts vers le bas, d'autre part la zone de dérive des coûts vers la droite (en effet, une modification non prévue peut être à l'extrême intégrée dans une alternative à étudier – ce qui annule la dérive – ou plus fréquemment engendrer des surcoûts dans la mesure où des choix avaient déjà été verrouillés, mais moindres que s'il fallait revenir plus en arrière dans le cycle de vie et reprendre des portions plus importantes des étapes précédentes).

Si l'on compare alors deux trajectoires particulières, d'une part pour un système acquis « traditionnellement », d'autre part pour une acquisition intégrant pleinement la simulation, on voit alors trois gains apparaître :

1) des coûts engagés par avance inférieurs,
2) une dérive de coûts moins importante,
3) des coûts engagés par avance, après dérive, inférieurs.

La totalité de ces gains dépasse rapidement le surcoût de la simulation par l'acquisition calculé précédemment : avec les simples hypothèses qualitatives de ce paragraphe, on voit que c'est le cas dès que l'on aborde l'étape de développement.

En fait, ce simple calcul est même trop pénalisant pour la simulation pour l'acquisition : en effet, le surcoût calculé précédemment l'est sur toute l'acquisition du système, et il ne faudrait le calculer que sur la période jusqu'à la dérive de coûts. Et quand on regarde les calculs précédents, on voit que ce sont les étapes de fin de développement et de production qui contribuent le plus au surcoût de la simulation pour l'acquisition, donc après le moment où la simulation pour l'acquisition est déjà rentable. Une analyse rapide montre que qualitativement les gains en dérive de coûts et en coûts engagés par avance absorbent à tout instant le surcoût au même instant entraîné par un processus de simulation pour l'acquisition en comparaison d'une acquisition « traditionnelle ».

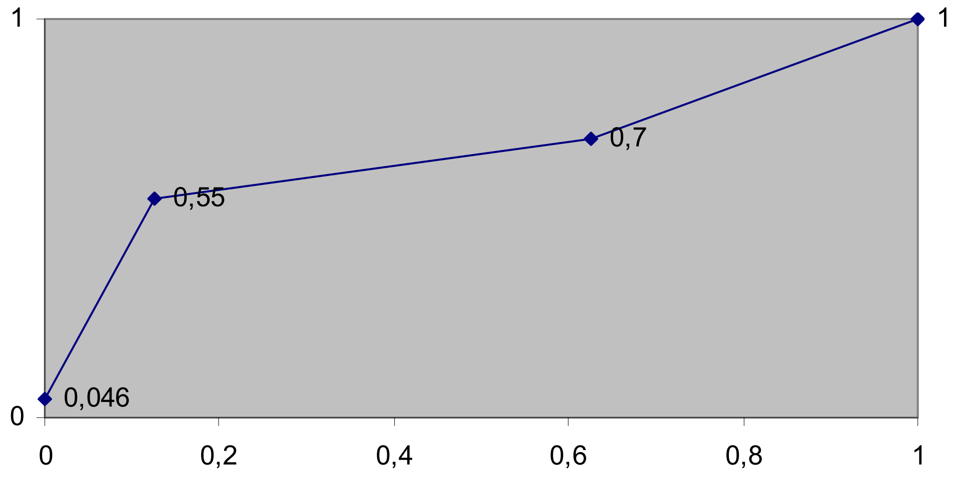
En conclusion, on vient de démontrer qu'un processus de simulation pour l'acquisition (à l'instar de la qualité) engendre un surcoût immédiatement absorbé et transformé en gain dès le premier imprévu.

2.3.3 Cas d'une acquisition multiprojet

Nous sommes cette fois dans le cas de l'acquisition d'un système de systèmes. On pourrait bien entendu refaire l'analyse précédente, et cumuler les gains, qui vont nécessairement apparaître, car la probabilité d'un risque non maîtrisé croît plus rapidement que linéairement avec plusieurs équipes d'acquisition différentes travaillant sur des systèmes décalés au niveau de leur cycle de vie, et devant ensuite être intégrés conjointement.

Cependant, nous allons faire une autre analyse économique, pour mettre en évidence les intérêts de la *réutilisation*.

Dans la mesure où les simulations font intervenir une part importante de logiciel (y compris comme logiciel plus ou moins enfoui dans des simulateurs hybrides avec du matériel dans la boucle), nous prendrons les modèles de coûts sur la réutilisation issus du monde de l'ingénierie logicielle, et en particulier le modèle COCOMO2.0 (constructive cost model), introduit dans la première version par Barry Boehm en 1981, puis étendu en 1987 et en 1995, la dernière version prenant en compte de manière détaillée les problèmes de produits sur étagère (les COTS), de réutilisation et de réingénierie logicielles. La courbe suivante, basée sur l'analyse de près de 3000 modules logiciels de la NASA menée par Richard Selby en 1988, donne le coût de réutilisation en fonction de la portion de logiciel à modifier.



On observe donc une économie importante quand la modification est inférieure à 10%, puis on peut estimer l'économie de l'ordre de 25 à 50% pour des modifications allant jusqu'aux alentours de 75%.

Dans le cadre de l'acquisition d'un programme, les simulations développées sont de plus en plus spécifiques au produit final, au fur et à mesure de l'avancée dans le cycle de vie. Typiquement, on peut estimer que les simulations sont potentiellement réutilisables en majorité pendant l'étape de faisabilité et a priori peu réutilisables pendant le développement (et a fortiori la production).

Au vu de la courbe précédente, la réutilisation offre une économie importante pendant l'étape de faisabilité, puis une économie de l'ordre de 25% pendant la définition et partie du développement.

Or, si l'on se réfère aux courbes de la section précédente sur la part relative de la simulation dans l'acquisition d'un système, celle-ci occupe quasiment toute l'étape de faisabilité, et une portion non négligeable de la définition et du début du développement, quel que soit le mode d'acquisition, « traditionnelle » ou SBA.

Pour une acquisition de système de systèmes, où plusieurs cycles de vie sont superposés, avec des décalages correspondant à l'état d'avancement de la vie de chaque système, la réutilisation permet des gains très importants sur la faisabilité des nouveaux systèmes et des gains non négligeables sur les étapes de définition.

D'une part les financements économisés peuvent être réaffectés sur les aspects d'intégration des divers systèmes (on « gagne » ainsi des étapes de faisabilité et de conception du métasystème), d'autre part on maîtrise davantage les risques (cf. analyse de la section précédente).

En conclusion, cette analyse qualitative sommaire montre que **la capacité de réutilisation prônée par la simulation pour l'acquisition de plusieurs systèmes (ayant évidemment un certain potentiel d'utilisation combinée et de cohérence d'ensemble) peut être réinvestie pour la conception du métasystème les organisant**. Un changement de méthode de travail permet donc de passer d'une somme de systèmes à un système de systèmes : on s'est ainsi donné les moyens d'atteindre l'objectif de logique capacitaire énoncé au début de l'article.

3.0 SIMULATION POUR L'ACQUISITION DE LA BOA

S'inscrivant dans la démarche générale présentée précédemment, la simulation pour l'acquisition de la BOA a pour objectif d'évaluer techniquement et opérationnellement, à l'aide de la simulation, les différentes architectures techniques susceptibles de constituer la BOA, compte tenu du besoin et des contraintes (risques techniques, coûts, délais, etc.) associés aux programmes d'armement.

À l'issue de l'ensemble des phases d'évaluation de chaque architecture, il doit être possible de choisir la meilleure architecture compte tenu de la métrique (une mesure de performance suivant des critères donnés) appliquée, et de pouvoir spécifier globalement les performances des éléments qui auront été simulés en vue de la phase de faisabilité des programmes d'armement associés.

La démarche d'acquisition est en cours, et les éléments suivants extraits du cahier des charges illustrent les grandes lignes de ce qui est attendu.

Il s'agit donc de réaliser un environnement de simulation qui permette :

- dans le cadre de la préparation d'une campagne de simulation, de définir :
  - des architectures et des SGTIA (sous-groupes tactiques interarmes : c'est la plus petite unité opérationnelle considérée ; elle ne suit pas nécessairement les compositions actuellement en vigueur, un des objectifs de la simulation étant une éventuelle révision de certaines doctrines d'emploi) représentatifs de ces architectures,
  - des théâtres d'opérations (environnement naturel, infrastructures) dans lesquels évolueront l'ensemble des acteurs de la simulation (unités du SGTIA, unités coopérant avec le SGTIA, unités ennemies, etc.),
  - des unités coopérant avec le SGTIA (y compris les autres unités au niveau GTIA ; on travaille donc simultanément avec diverses organisations de commandement),
  - des unités ennemies du SGTIA,
  - les scénarii représentant l'évolution dans le temps des différents acteurs sur le théâtre d'opérations,
  - l'ensemble des métriques qui seront utilisées pour l'évaluation technique et opérationnelles des architectures,

- de simuler, de façon éventuellement interactive, les comportements des différents acteurs compte tenu du scénario, du théâtre d'opérations, et de l'architecture choisie,
- d'exploiter les résultats des simulations afin d'évaluer les performances techniques et opérationnelles de l'architecture définie compte tenu du théâtre d'opérations choisi, des forces en présences, du scénario et des objectifs associés, etc.

Il s'agit également de créer une bibliothèque de modèles génériques (canons, détecteurs d'alerte, etc.), qui pourront être agrégés afin de constituer les systèmes (systèmes de communication, systèmes d'armes ou unités, senseurs, etc.) existants ou à venir. Cette agrégation peut faire intervenir des modèles liés aux problématiques d'intégration : la généricité des modèles permettra alors de créer et simuler une large gamme de véhicules et de systèmes. L'ensemble des agrégats de modèles et leurs interactions (internes ou externes) est appelé « concept système ».

Les forces ennemies utilisées lors des simulations sont créées par le même principe, avec une granularité et un niveau de représentation équivalente ou éventuellement moindre.

Des outils permettent la gestion des modèles (données et paramétrage) et des agrégats de la bibliothèque.

Le concept système et son architecture sont évalués dans un environnement (naturel et opérationnel) synthétique, compte tenu d'un scénario préparé à l'avance et saisi dans l'outil de préparation à la simulation. Ceci permet donc d'évaluer des organisations globales de la BOA avec des concepts systèmes EBRC variés. Il sera instructif d'évaluer l'influence des concepts systèmes sur la performance d'une architecture globale l'intégrant. *On voit immédiatement la potentialité de la simulation dans cette phase d'exploration de concepts, où l'analyse multidimensionnelle et multicritère ne saurait se satisfaire de la simple étude papier de quelques architectures cibles que l'on estimerait a priori représentatives des principales options.*

Les outils développés permettent d'évaluer les différentes architectures à partir de paramètres pertinents extraits des simulations réalisées. L'évaluation comprend aussi bien des critères d'évaluation de la capacité opérationnelle de l'architecture testée que des critères financiers, techniques, ou technologiques.

Parallèlement aux études d'ingénierie et de réalisation de l'environnement de simulation, des architectures de validation pour la BOA doivent être proposées. D'une part, elles permettent de disposer d'architectures pertinentes pour la validation de l'environnement de simulation à mesure de son développement et de vérifier tout au long du développement que l'environnement de simulation permet de simuler une grande variétés d'architectures différentes. D'autre part, elles servent de support à l'élaboration des métriques qui seront utilisées pour classer les architectures lors des exploitations.

Un certain nombre d'exigences ont été formulées en termes de principes et standards à respecter :

- l'environnement de simulation (simulateur et outils) doit être conçu pour garantir une ouverture maximale (l'ouverture est la capacité à évoluer suite à une évolution des besoins et des technologies, pour le simulateur, cela comprend par exemple : la capacité d'ajout ultérieur de modèles, éventuellement par un tiers, la modification des modèles existants, l'ajout et la modification des capacités de visualisation, etc.), et pour simuler la plus large gamme d'architectures possibles pour la BOA ;
- le simulateur est conforme à la norme HLA (la certification n'est pas exigée mais le simulateur pourra néanmoins être fourni à un organisme de certification HLA) ;
- la base de données d'environnement associée au simulateur respecte le format SEDRIS.

Cette ouverture est fondamentale pour pouvoir servir de noyau à une démarche de simulation pour l'acquisition : en effet, la vie des simulateurs ne s'arrête pas dès l'évaluation et le choix d'une ou plusieurs architectures système. Cette simulation est une étape de base pour les phases de conception des systèmes d'armes à venir qui vont s'intégrer au sein de la BOA. Afin de faciliter cette réutilisation, il a été fait le choix d'imposer un certain nombre de standards actuels, dont une certaine pérennité (et a priori une compatibilité ascendante en cas de changement majeur de format) semble garantie sur les années à venir.

Par ailleurs, dans le cas du lancement d'un développement international, grâce à l'ouverture du système (et aux exigences de sécurité sur la confidentialité de l'accès aux données et modèles en cours de simulation), il sera possible d'évaluer des concepts systèmes et/ou des architectures avec des choix de modèles de systèmes étrangers. Chaque partenaire sera donc en mesure d'évaluer un éventuel concept commun au sein de son propre métasystème.

Le simulateur et les outils associés (environnement de simulation) seront déployés sur plusieurs sites géographiques, maintenus en condition opérationnelle et gérés en configuration. Après déploiement du simulateur, il y aura une première phase d'utilisation avec des propositions d'architectures fournies par l'administration au titulaire maître d'œuvre. Durant cette phase le titulaire proposera et mettra en œuvre des métriques pertinentes afin de classer les différentes architectures qu'il aura évaluées. La phase de maintien en condition opérationnelle suivra, l'utilisation et la mise en œuvre étant alors effectuées par l'État.

Cette répartition des responsabilités est essentielle dans la mesure où la démarche de simulation par l'acquisition est cruciale pour les phases de préparation de systèmes d'armes à venir, et afin de garantir des mises en concurrence ultérieures non biaisées, une maîtrise de l'outil d'analyse et d'évaluation de concepts est nécessaire.

4.0 CONCLUSION

Le souci de définir l'outil de défense de demain en termes capacitaires oblige donc à faire évoluer les méthodes d'ingénierie des systèmes et à être capable de proposer aux architectes, à tous les niveaux, des outils de modélisation et de simulation adaptés pour l'aide à l'analyse, à la conception, à la réalisation, à l'évaluation, voire à la gestion de configurations et à l'entraînement des systèmes de défense du futur. La cible idéale serait une communauté d'outils, de méthodes et de normes entre les différentes parties prenantes : États-Majors, DGA, industrie.

La maîtrise de l'outil général de modélisation et de simulation constitue un élément essentiel pour peser sur les choix en matière de systèmes de défense dans des cadres d'acquisition ou de mise en œuvre internationale (OCCAR, OTAN…).

Un des objectifs de cet article a été de donner une justification économique à ces nouveaux modes d'acquisition fondés sur une utilisation de la simulation de manière complètement intégrée sur l'ensemble du cycle de vie du système.

Les analyses économiques faites dans cet article doivent évidemment être raffinées, en reprenant les différentes approximations (non-linéarités, convolution des coûts et ratios d'utilisation de la simulation), en introduisant par ailleurs des modèles de coûts non constants par étape du cycle de vie (des courbes en cloche semblent pertinentes, d'après des retours d'expérience en aéronautique) conduisant alors à des courbes cumulatives de coûts qui ne seront plus linéaires par morceaux, en introduisant explicitement les coûts d'intégration (horizontale, et verticale, c'est-à-dire systèmes de rang inférieur) et de réutilisation.

En tout état de cause, la démarche de simulation pour l'acquisition est actuellement déroulée pour la capacité de combat aéroterrestre, et les divers programmes concernés à venir. L'avenir dira si elle a tenu les promesses, et le retour d'expérience devrait être instructif en termes de méthodes d'acquisition de programmes d'armement.

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Non-Hierarchical Approach to Couple CCIS with M&S

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ABSTRACT

The use of the term interoperability in certain areas of information technology is also predominant in the military community when talking about multinational Command and Control Information System Environments (CCIS) and Modeling and Simulation (M&S). The Multilateral Interoperability Program (MIP) on the one hand and the Simulation Interoperability Standards Organization (SISO) on the other hand prevail among others.

Either community typically has different meaning of the term interoperability and they run dangerous of getting separated whereas unification is even more desirable. Instead of a bottom-up approach ("interoperability by means of technology") a top-down view may help to better understand the real system, which is the one military combat space.

Information flow initially drives the system, hence the system becomes the response function which to some extent generates additional information flow. This generic interpretation of the system gives reason for a non-hierarchical alignment of CCIS and M&S taking into account their domain specific interoperability technologies, like e.g. MIP or HLA.

The GE and US Simulation and CCIS Connectivity Experiment (SINCE) is to become a proof of concept project in a sense of loose coupling CCIS and M&S environments. The paper describes the top-down approach in correspondence to the SINCE four phase experimentation program. The GE technical architecture is outlined in detail.

INTRODUCTION

The term interoperability is commonly being used in different areas of military information technology. Superficially spoken, it refers to the low level capability of different information systems to exchange information content among each other. The IEEE Glossary [01] gives us a quite short definition of Interoperability:

> *The ability of two or more systems or components to exchange information and to use the information that has been exchanged.*

This indicates one should expect that the systems communicate information contents reasonably based on sensible requirements rather than only handling bits and bytes. Such a sensible requirement is to cooperatively link different Command and Control Information Systems (C2IS) becoming more and more important by the implications of the multinational Warfighter.

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Adequate support of the Command and Control process includes the use of military operations research and analysis and other areas of military simulation of an anticipated synthetic threat environment[1]. Instantly, three different instances of interoperability occur within one single cooperative environment:

- C2IS Interoperability
- Simulation System Interoperability
- C2IS / Simulation Interoperability

These become the essential pillars in interoperability technology as needed in military decision making processes, training and exercise, mission rehearsal and last but not least, simulation based acquisition (SBA). And, as elaborated in the following chapters, this also implies that the mission space concept is the most essential prerequisite at the bottom line. The U.S. formerly have called it the Conceptual Model of Mission Space (CMMS), an underlying conceptual view on the military operations and objects in space and time.

The CMMS idea claims a top-down approach in contrast to the bottom-up trial of practicing interoperability by means of technology (data structures, networks and protocols). The US-GE SINCE[2] program is to establish a new way for doing collaborative planning and mission rehearsal serving the new challenges of multinational military operations [07]. The SINCE environment aims to leverage from off-the-shelf technologies, e.g. NATO STANAGs in the area of interoperable M&S and C2IS.

ASPECTS FROM SYSTEM THEORY

From a simulation point of view the combat space evolves with time t as a system of mutually interacting components, or let's say objects. The entire system's state at a time t is well defined in accordance with each single object's state at time t, where the state of a single object may be defined by the values of its attributes at time t.

A question arises what drives the system initially over time. A tank engine for example, which enables the tank to alter its location, appears to be an indirect driver mechanism unlike the initial decision to force the tank commander to start his engine to move the vehicle. In other words, information content and its flow initially drives the system. Dynamics originate from information flow in combat. From this observation it becomes clear that neither simulation nor information systems exist as independent autonomous subsystems but only sustain in coexistence.

A system theoretical approach based on abstract mathematics could be very helpful to better understand the behavior of a system. But analysis still lacks from a fundamental statistical baseline as a foundation for what physics call invariants (like energy) and generalized system co-ordinates (like location and momentum).

Momentarily, for the sake of simplicity, we seek for a coupled environment which enables us to reflect the stimulus from the C2IS in the simulated (virtual) world and to feedback from there the combat status at a later time-point [5]. This is to control cause and action, i.e. information flow and simulated combat, to better support training and education (CAX), collaborative planning and decision making close to reality.

[1] Remember STRICOM's slogan *All But War Is Simulation.*

[2] Simulation and C2IS Connectivity Experiment.

STANDARD TECHNOLOGIES

In 1996 the U.S. DoD Modeling and Simulation Office (DMSO) has outlined the High Level Architecture (HLA) as a future standard for distributed simulation [02] thus continuing IEEE 1278 (DIS) and the national Aggregate Level Simulation Protocol (ALSP) efforts. The HLA comprises communication services as a baseline for any sustainable simulation application, either legacy or new, to interact with any other simulation application (the so called federates).

The HLA does not incorporate any specific data model but specifies a template form (OMT for Object Model Template) to allow for implementing various data models as needed (so called Simulation/ Federation Object Models SOM/ FOM). As a matter of fact, the OMT requires only the naming of distributed objects and their attributes including publication and subscription properties but not their meaning. However, HLA fully captures know-how and expertise from DIS and ALSP and combines publication of objects with time-managed behavior of their states and interactions. HLA is not a starting point for a CMMS but a kind of smallest denominator to transport the corresponding information contents down to the OMT level.

In April 1998 the Multilateral Interoperability Program (MIP) started with the aim to achieve international interoperability of C2IS at command levels in order to support combined and joint operations, and to benefit from the progress of digitization of the battlefield in the international arena, including NATO.

In 2001 MIP succeeded in two Phases: Phase 1 to achieve interoperability by a Message Exchange Mechanism (MEM) and Phase 2 using a Data Exchange Mechanism (DEM). Both Phases have joined in 2002 based on the common Land C2 Information Exchange Data Model as the so called MIP Common Data Model (MCDM).

To date, MIP has not had any interrelation with distributed simulation technology although several programs demand from simulation to cope with C2IS as the aforementioned SINCE does.

Consequently, two independent architectural approaches for interoperable system design do exist in parallel and the SINCE program is an example for emphasizing the overlapping aspects in a heterogeneous confederation of operational and simulated components.

NON-HIERARCHICAL COUPLING

There is no doubt that analytical solutions are best suited for better understanding a system's behavior. Simulation technology seems to be the most promising tool to cope with complex system behavior, provided that there exists an accepted sophisticated model behind. However, we must notice that the IT community is manifold and tends to increase diversification according to a lot of different requirements in the user community. Consequently, HLA, CMMS and the MIP were launched separately and independent from each other. Although an abstract higher level approach is still missing, a starting point for an analytical effort to balance information flow and combat dynamics would benefit from a conceptual model of mission space being independent of any specific M&S and C2IS representational aspects. This is analogous to a point in space which is relative with reference to a co-ordinate system but absolute in accordance with an object located at this point.

This features the importance of an absolutely defined military mission space and – speaking IT – a corresponding structured data model with the ability to cover both military information flow and combat dynamics with time. Taking into account the above mentioned diversification in IT, overlapping system aspects for a coupled solution (C2IS vs. SimSys) have to be identified carefully in order to merge the simulation's world with the C2IS world properly and to avoid unexpected intrusive alterations in each system's interoperability arena.

It seems to be common sense to keep the worlds – M&S and C2IS – loosely coupled if possible. We would call this the *non-hierarchical coupling concept* when based on an independent model to avoid any influence on the interoperability concepts in each respective area. In correspondence to the former mentioned system theory approach a CMMS is to be the generalized co-ordinate system while each specific application area uses its own canonical reference model, best suited for C2IS and M&S purposes, respectively. In fact, the IT community sometimes uses the term *Data Interchange Format (DIF)* which denotes the ability to move from one specific representation to another by intersecting a common reference point (here the DIF) instead of applying proprietary point-to-point transformations. Mathematics calls this *transitivity*: If A relates to C and C relates to B, then A relates to B. Thus, the DIF (the C) makes it possible to size a cardinality of n^2 relationships down to n.

Apparently, the notion of the DIF itself is a problem of international negotiation because of its multinational, joint and combined nature.

From hereon we conceive the existence of such a conceptual reference model (CRM) hypothetically, and furthermore, we assume to have a corresponding object-oriented CRM at hand, so to say a structured implementation, a data model. This can be abstract for almost all aspects of dynamics, but nonetheless, it has to span the military combat space by means of its object definitions; each object definition, or class, denotes a co-ordinate in a multi-dimensional space, filled by an infinite number of the system's states.

Now, the CRM serves as a unique root for any further instance of any other object model with the help of inheritance and dynamics implementation.

E.g., a HLA-federation based on a specific FOM would then have to be derived from the CRM:

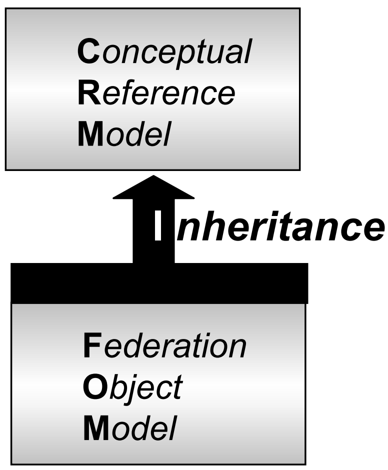

Figure 1: Canonical Data Models (here a FOM) Gained by Inheritance from the CRM.

Each object model derived from the CRM is a specific representation of a specific part of what the CRM represents conceptually. E.g., a simulation federation which deals with battalions and platoons may not address the higher resolution aspects like weapon platforms. In other words, this would be an aggregated view on the CRM's high resolution entities, thus the derived data model typically inherits only fewer parts of the CRM.

With respect to our situation of coupling the C2IS and the simulation space, by theory we have to consider two derivations, either a FOM-like and a MIP-like data model being involved:

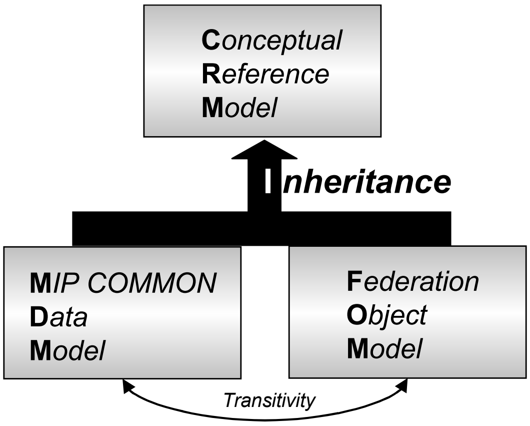

Figure 2: Two Canonical Representations and Concurrent Implementations Based on One CRM.

From the former transitivity argument we conclude that by construction and requirement this ensures a proper relationship between the data model instances underneath the CRM.

IMPLEMENTATION ISSUES

The last figure sketches an approach for a software architecture to couple the spaces under consideration:

The relevant software component is (a kind of) a gateway which mediates among different underlying transport mechanisms for each coupled space. More abstractly spoken, it is a projector mapping one representation of combat space into another and vice versa. We call the appropriate mechanism the *Command and Control to Simulation Proxy* (C2SIM-Proxy). The advantage of the C2SIM-Proxy is that it encapsulates and hides the placeholder for a yet non-existing CRM instance.

Furthermore, Figure 2 degenerates to Figure 1 when setting CRM=MCDM. This is the SINCE project's approach for its first phase. However, it is expected that the collaborative planning process as a central requirement of SINCE cannot be covered without extensions to the MCDM. Therefore, a second phase in SINCE requires iterative refinement of the CRM thus leading us to a more distinctive architecture to catch the situation of multinational planning environments:

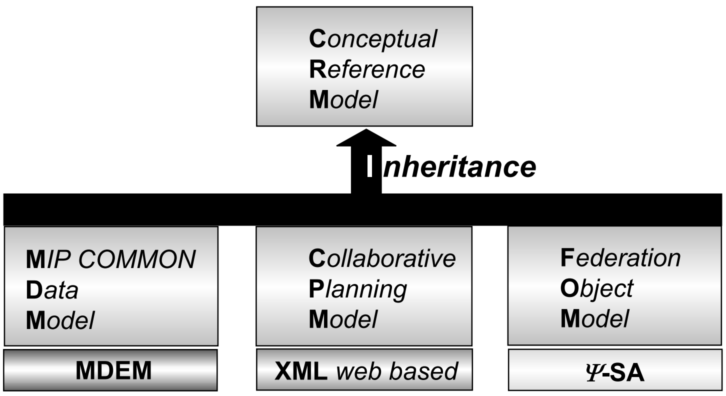

Figure 3: C2SIM-Proxy Architectural Design in Support of Collaborative Planning Beyond the MIP.

Each single bottom layer denotes a domain-specific communication infrastructure for dedicated information transport:

1) *Ψ*-SA[3] is a specific German infrastructure technology to encapsulate the HLA OMT in an object oriented manner [3], thus in close neighborhood to any possible object-oriented CRM,

2) the MIP Data Exchange Mechanism (MDEM) is more or less the well known ATCCIS Replication Mechanism (ARM) to synchronize the various C2IS components [4],

3) the SINCE Technical Working Group recently has decided for a XML based exchange of relevant planning data.

According to figure 3 the C2SIM-Proxy consists of three data models each of which represents the corresponding view with respect to each military activity branch. The CRM on top serves as the common root for the C2SIM-Proxy to mediate between those operational data models in support of synchronizing the specific activity branches from C2IS (statics) over collaborative planning (dynamic profile) to simulation (combat dynamics).

The software development process starts with a use-case analysis to identify the different space representations in terms of objects and interactions of mutual interest.

FINAL CONCLUSIONS

The international efforts on interoperable C2IS environments recently resolved in a MIP Common Data Model (MCDM) which helps to follow the path towards a conceptual reference model (CRM) of mission space to be applied for various application areas such as the collaborative planning and decision making process supported by M&S. However, the technical standards in either arena, HLA and MIP, are not based upon modern object oriented approaches to capture the dynamics of the entire system evolving with time. A corresponding CRM plays this central role within a C2SIM-Proxy and paves the way to reasonably couple the disparate representations of the one same combat space.

The C2SIM-Proxy leverages from the recent evolutionary results in the MIP and the M&S communities, and establishes a mechanism to link those representations in a non-intrusive way. SINCE is currently topping this sequel of developments, jointly utilizing each participant's resources and available results of former activities. For Germany the major thrust will be in the practical design and testing of the proxy functionality in a collaborative environment [06]. Beyond that, the basic functionality of the C2SIM-Proxy will also be incorporated in current and future projects in the area of Simulation Based Acquisition as well as Integrated Test and Evaluation, creating a comprehensive Synthetic Environment which is to be expanded beyond national borders by the concepts on so-called Virtual Proving Grounds.

This implies that these efforts continue to be of international relevance. After Experiment 1 of the SINCE project, the results will be leveraged to the NMSG[4] with the option of other nations joining the follow-on experiments by adopting the concept.

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AUTHOR'S BIOGRAPHY

Dr. rer. nat. Hans-Peter Menzler studied physics at the University of Osnabrueck, Germany, and earned his PhD in applied mathematical physics in 1989. He worked for three years as a scientist at the Max-Planck Institute for Plasma-Physics. In 1992 he became a system engineer and project manager at Competence Center Informatik GmbH (CCI) where he primarily focused on object oriented distributed simulation. In April 1999 he became head of the simulation infrastructure section at WTD 81, Greding, where he developed his concept and implementation of Ψ-SA and recently launched the C2SIM-Proxy concept.

Dipl. Ing. Michael Sieber studied Electrical Engineering at the Armed Forces University in Munich and earned his Masters Degree in 1981. After his military career in various technical and staff domains he joined the WTD 81, where he was responsible for research programs in communications including the German military satellite communications program. Other assignments were as a consultant to the OR division of the former SHAPE Technical Centre in The Hague and to the Directorate for Maritime Combat Systems at the Department for National Defence in Hull, Canada. Currently he heads the Information and Communication Systems Simulation Branch at WTD 81.

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Perspectives on the Use of M&S to Support Systems Acquisition

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Abstract

There is increased interest in the use of innovative modeling and simulation (M&S) tools to support the acquisition of defense systems. This paper discusses the results of two recent activities that were convened to shed light on this issue: a study by the National Research Council (NRC) entitled "Modeling and Simulation in Manufacturing and Defense Systems Acquisition: Pathways to Success" and a workshop sponsored by the Office of the Secretary of Defense (OSD) on "M&S to Support C4ISR Acquisition and Transformation". The paper concludes by identifying the major common themes that emerged from the two activities and potential next steps.

A. Introduction

This paper identifies and discusses recent perspectives that have emerged on the use of modeling and simulation (M&S) to support the acquisition of defense systems. The paper begins by identifying and analyzing key trends that are likely to affect the acquisition of defense systems over the next decade. Consistent with these factors, a vision for a reformed acquisition process, simulation based acquisition (SBA), is introduced. The paper then derives key insights on SBA that have emerged from several recent events. The first event is a National Research Council (NRC) study entitled "Modeling and Simulation in Manufacturing and Defense Systems Acquisition: Pathways to Success". The basic facts of the study are summarized and the major study recommendations are presented and discussed. That is followed by a description of the second event, a workshop sponsored by the Office of the Secretary of Defense (OSD) on M&S to Support C4ISR Acquisition and Transformation. That event is characterized by the insights that were developed in plenary and a summary of the major recommendations that were developed by the

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workshop's break-out groups. The paper concludes by identifying the major common themes that emerged from the two events and potential next steps.

B. Context

As context for this paper, this section briefly analyzes trends affecting Department of Defense (DoD) acquisition needs and formulates a new acquisition vision.

B.1 Trends Affecting DoD Acquisition Needs

There are several major trends that will affect the M&S and ancillary tools that are needed to support the acquisition of military systems. These trends are depicted in Figure1. The following discussion identifies these trends and discusses their implications on the use of M&S in the acquisition process.

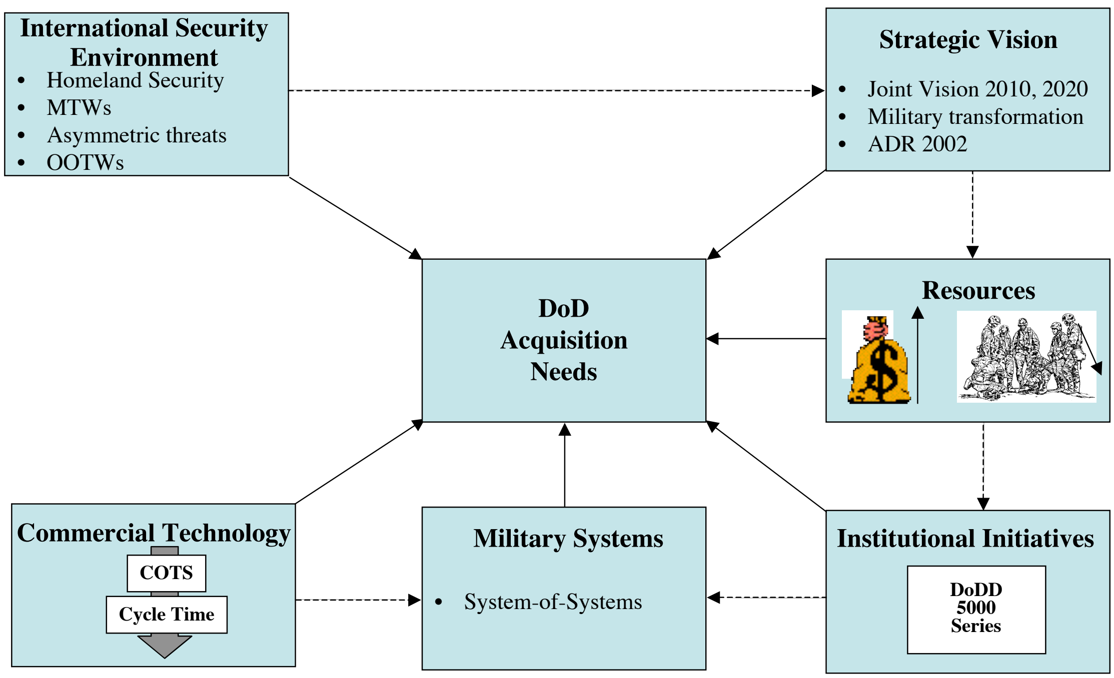

Figure 1. Trends Affecting DoD Acquisition Needs

B.1.1 International Security Environment

The dawn of the 21st century has given rise to several fundamental changes in the international security environment. In the aftermath of September 11, 2001, there has been a dramatic increase in the attention paid to homeland security issues. Although the interest in potential major theater wars (MTWs) has also persisted, the recent focus has been on states that have access to chemical, biological, radiological, nuclear, and explosives (CBRNE) weapons. There is particular concern that these actors could use such weapons asymmetrically to pose anti-access issues that would create challenges for conventional forces. In addition, there is the realization that operations other than war (OOTW) (e.g., peacemaking, peacekeeping) are likely to recur, prompting the need to create *ad hoc* coalitions of willing nation states, international organizations, and non-governmental organizations.

Currently, there are few existing M&S that are well suited to address these issues. Thus, a new generation of M&S must be developed for these conflict environments that can support the trade-off studies needed to explore meaningful break-points in mission capabilities.

B.1.2 Strategic Vision

Over the last five years, a series of strategic products has emerged to guide the DoD's responses to these changes in the international security environment. At the base of these products lies Joint Vision 2010 and 2020 (Reference 1, 2) issued by the Chairman, Joint Chiefs of Staffs. Those visions emphasized that enhanced command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) will be the critical enabler for transforming the US's military force. Building on that vision, the Secretary of Defense in his Annual Report to the President and the Congress (ADR) (Reference 3) has identified six transformational objectives to focus the actions of the military. Those objectives also identify C4ISR as a major direct and indirect factor in the proposed transformation.

At present, there are relatively few M&S that credibly reflect C4ISR processes and systems. Thus, efforts are needed to deal creatively with this dimension of the problem, either by incorporating the effects of C4ISR in existing or proposed M&S, or by interfacing M&S with operational C4ISR systems. In addition, those latter experiences could be used to collect the data needed to improve modeling of C4ISR.

B.1.3 Resource Trends

Within the last year, there has been a renewed commitment by the US to devote increasing resources to national security. This increase reflects the demands from multiple needs: enhanced attention to homeland security, as well as the need to sustain selected legacy forces while pursuing transformational goals. Even though those resources are substantial, they are inadequate to deal with all the national security demands for resources. As an example, the Crusader, a highly automated artillery system, was cancelled to free up resources for more pressing systems. Thus, there will continue to be strong pressure to acquire the "right things" as well as acquiring "things right". Consequently, there will be increasing need for M&S tools that will help the senior leadership understand which are the "right things" with an emphasis on proceeding with only those ongoing acquisitions which support future system-of-systems concepts.

In order to reduce the military footprint in the theater and reduce resource requirements, there is interest in acquiring systems that require fewer personnel to operate them. To support that concept, there is interest in acquiring M&S that support much more effective education and training, any-where, any-time.

B.1.4 Institutional Initiatives

There is growing concern that the current acquisition process is stultifying, limiting the Program Manager's creativity and flexibility, and is too focused on the acquisition of individual systems vice military capability. As a consequence, a revision of DoD Directive (DoDD) 5000 is in progress that is briefer, less directive, and incorporates system-of-systems acquisition. Current drafts of the revised documents emphasize processes such as evolutionary acquisition and spiral development. Clearly, there is a need for enhanced M&S tools and ancillary data to help implement these concepts, particularly to address the complexities inherent in mission capabilities and system-of-systems acquisition issues.

B.1.5 Military Systems

Historically, the acquisition of systems focused on individual platforms, keeping most key operational and support factors fixed (e.g., concepts of operation, education and training). There is increased understanding that one needs to acquire and assemble systems-of-systems to realize enhanced mission effectiveness. This appreciation has led to increased emphasis on interoperability along with the recognition that testbeds or environments are needed to assess, achieve, and sustain it. In addition, the interest in transforming the military has stimulated the re-thinking and re-orienting of all aspects of doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTML-PF). Currently, existing tools lack the flexibility to vary all of these factors simultaneously. Thus, attention is being given to new M&S techniques (e.g., agent based modeling) which have the potential to deal flexibly with a broader set of these factors and their interrelationships.

B.1.6 Commercial Technology

In recent years, there has been a dramatic increase in the use of commercial-off-the-shelf (COTS) technology in military systems, particularly for C4ISR systems. These COTS products tend to be highly dynamic, spawning upgraded versions on the order of 6 to 18 months. Since this is much shorter than the historical DoD acquisition cycle, it is stimulating the use of innovative acquisition strategies (e.g., evolutionary acquisition) to avoid fielding products that are technologically obsolete. To support this process, there is a need for M&S testbeds to explore the value of injecting new technology on mission effectiveness, in a timely manner.

B.2 Acquisition Vision

To respond to these major trends, a vision of a new acquisition paradigm is emerging that yields substantial reductions in time, resources, risk, and total ownership costs throughout the life cycle process, while simultaneously increasing the system's quality, military worth, and supportability.

In order to achieve those benefits, it is perceived that the intelligent use of simulations is the critical enabler. These simulations must be robust, used collaboratively by all of the stakeholders involved in the acquisition, and integrated across the phases and functions of the system life cycle. In addition, to take full advantage of the investments in these simulations, steps should be taken to ensure that they are reused to support other, related system programs. This philosophy of employing M&S extensively and consistently within and across program lines is often referred to as Simulation Based Acquisition (SBA).

C. Key Insights

Over the last several years, several activities have explored options to enhance the use of M&S to support system acquisition. This section characterizes the insights that have emerged from two of those activities: a NRC study and an OSD-sponsored workshop.

C.1 National Research Council Study Results

In 2001, the Defense Modeling & Simulation Office (DMSO) requested that the NRC investigate next-generation evolutionary and revolutionary M&S capabilities that will support enhanced defense systems acquisition. The NRC is the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing analytical services to the government, the public, and the scientific and engineering communities. The study was chaired by Peter Castro, Eastman Kodak Corporation, and performed by a committee of twelve experts on M&S, manufacturing, and acquisition, drawn from academia (i.e., Harvard, California Institute of Technology, University of Arizona, Carnegie Mellon University, Old Dominion University, Johns Hopkins University/Applied Physics Lab, and the University of Wisconsin-Milwaukee), industry (i.e., Lockheed Martin, Ford, GRCI), and Federally Funded Research & Development Centers (FFRDCs) (i.e., MITRE, and Sandia National Labs,). This group received extensive briefings from, and conducted in-depth discussions with, innovators in SBA in government and industry. The final report was issued in the summer of 2002 (Reference 4).

The NRC Panel proposed four, broad, inter-related recommendations. As a key enabler, it is vital that the community invest in appropriate technology and research. The results of these efforts will give rise to a community-wide infrastructure that supports increased consistency and integration. Use of that infrastructure will provide experience that will guide further use as well as pointing to important opportunities for further research. Finally, people and culture are the key factors: if the people and the culture in which they operate do not trust and embrace the creative application of M&S to acquisition, SBA will never become a wide-spread activity.

The Panel characterized this set of recommendations as a “virtuous, auto-catalytic cycle”. That meant that each of the recommendations will serve to stimulate and reinforce the others. Thus, once a critical mass is achieved, the activities will be self-sustaining. However, it underscores the fact that failure to perform one or more of these recommendations could undermine the entire enterprise.

C.1.1 Technology and Research Recommendations

In the broad area of *technology and research*, the Panel recommended that “Long term R&D should be funded, conducted, and applied to enhance the science and technology base for M&S in … manufacturing, acquisition, and life-cycle support of military systems.” To amplify on that overarching recommendation, the Panel formulated four subordinate recommendations for DoD:

- Conduct or support *basic research and development* in the following areas: modeling methods (e.g., scalability, multi-resolution and multi-viewpoint modeling, agent-based modeling); model integration (e.g., interoperability, composability); model correctness (e.g., verification, validation, and accreditation (VV&A)); standards (e.g., M&S standards for interoperability and modeling); methods and tools (e.g., for assistance in the translation of system requirements into system functionality); and domain-specific models (e.g., M&S for operations other than war).
- Enhance the ability to deal with *systems-of-systems.* This should include the generation of a library of composable system models, the ability to manage interactions among component systems efficiently, and the development of efficient experimental design techniques.
- Create a *research initiative at multiple universities.* This initiative should focus on the key M&S shortfalls identified by DoD program offices.
- Plan and execute the *transition of research into applications* as an integral part of the development process.

C.1.2 Infrastructure Recommendations

In the area of *infrastructure for M&*S, the Panel recommended that the community should “…Invest in ‘common good’ activities to encourage standards and strong infrastructure for M&S”. To clarify that recommendation, the panel formulated three subordinate recommendations for DoD:

- Institute *incentives* for program managers to develop M&S elements that contribute to the general infrastructure. This should include an annual competition for the best infrastructure contributions.
- Exploit common elements of M&S to develop a *common infrastructure* capable of supporting consistency and interoperability across programs. This infrastructure should include common repositories that can support multiple phases of a program as well as multiple programs, a trained M&S workforce, and an information technology infrastructure that will drive the advance of the needed M&S infrastructure.
- Advance the emergence of *common standards* for performance simulation and product modeling. To that end, DoD should remain actively engaged in commercial standards efforts, take the lead in the development of standards that lack commercial interest, and develop standard semantics for the data elements used in DoD acquisition related M&S.

C.1.3 Use of M&S Recommendations

In the broad area of the *use of M&S* in acquisition and manufacturing, the Panel recommended that “Process improvements should be undertaken to better support integration of M&S within DoD’s system acquisition process.” To expand on that overarching recommendation, the Panel formulated four subordinate recommendations for DoD:

- Expand M&S in the *concept exploration phase*, to ensure that we “build the right thing” as well as “building the thing right". To that end, M&S should be used more extensively during the requirements process.
- Develop a *set of guidelines and best practices* for ownership rights among DoD and industry (with respect to M&S and data) to facilitate the potential for collaboration and the reuse of M&S.

- Define how M&S should be *integrated* into the DoD system acquisition process. This should include the use of the maturity of the simulation support plan as an element in milestone decision reviews.
- Create and implement *incentives* for DoD Program Managers (PMs) to adopt best practices on M&S use.
- Define and undertake *pilot efforts* at the OSD level. These pilot efforts should be designed to explore cross-program benefits of M&S and system-of-systems issues.

C.1.4 Culture and Human Issues Recommendations

In the area of *culture and human issues*, the Panel recommended that "…DoD must provide leadership to initiate, support, and sustain a cultural change in the acquisition process." To amplify on that overarching recommendation the Panel formulated three subordinate recommendations for DoD:

- *Fundamentally transform* the current acquisition culture in DoD into one characterized by collaboration, cumulative learning, agility, risk tolerance, learning from failure, and appropriate rewards and penalties.
- DoD should take the lead in collaborating with academia and industry to build the *intellectual capital* needed to implement SBA. This should include the support of existing and developing academic degree programs in M&S, the establishment of a mentoring program, and the encouragement of individuals to view M&S as a "lifetime learning" endeavor.
- DoD should establish a *center of excellence* for M&S in SBA. This resource would help create and promulgate the desired acquisition culture and enhance DoD's ties to the academic community.

C.2 OSD Workshop Results

The purpose of the OSD Workshop was to identify high priority M&S needs and recommend associated policy changes and initiatives to support the acquisition and transformation of C4ISR systems. Note that by focusing on C4ISR systems, this activity was more restricted in scope than the NRC study that addressed the acquisition of all DoD systems. However, during the course of the workshop deliberations, there was a sense that many of the issues faced in the acquisition of C4ISR systems map to those of complex battle management systems that integrate C4ISR and weapons systems. It is envisioned that the results will provide input to a subsequent investment plan for M&S to support the acquisition and transformation of C4ISR systems.

The Workshop was sponsored by three organizations in the OSD. They include the Assistant Secretary of Defense (C3I), and two offices in the Undersecretary of Defense (Acquisition, Technology, and Logistics): the Interoperability Office and the Defense Modeling and Simulation Office. To ensure a strong industry component to the workshop, the AIAA Technical Committee on Information and C2 Systems worked cooperatively with the workshop planning group to provide knowledgeable participants across the areas and in the synthesis activity.

The heart of any workshop is the experts that are assembled to deliberate on the issues of interest. In this case, forty-four experts on acquisition, C4ISR, and modeling and simulation were brought together. These experts provided a balanced mix of representatives from government, industry, and FFRDCs.

In order to achieve the goals and objectives of the workshops, a series of plenary and break-out sessions were held. In plenary, the sponsors proved individual charges to the participants. That was followed by presentations on institutional perspectives with emphasis on the DoDD 5000, governing the acquisition of systems. The plenary session concluded with Service presentations on innovative activities to enhance the acquisition of complex systems.

Subsequently, the assembled experts were divided into break-out groups by system type (i.e., communications, sensors, C2 systems/information processing) and systems-of-systems. Those break-out groups began their deliberations with a list of strawman M&S capability objectives. They evaluated associated M&S needs, and identified the highest priority M&S shortfalls. They subsequently identified options to ameliorate those highest priority shortfalls. The Workshop was held 2 - 4 April at the MITRE Corporation, McLean, VA (Reference 5).

C.2.1 Plenary Insights

The plenary session began with presentations by the workshop sponsors or their representatives. All see M&S as critical to their organization's mission effectiveness. With respect to systems-of-systems, all saw it as a wave of the future, which poses new M&S challenges for the community.

The presentation on DoD acquisition directives began by citing challenges in overcoming the shortfalls in the existing acquisition process (e.g., it takes too long, costs too much, and is incompatible with modern subsystem cycle times). The opportunities offered by the acquisition model described in the current version of DoDD 5000 were cited. It was stressed that the model emphasizes the use of evolutionary acquisition, anticipating the need to inject new technology periodically (e.g., on the order of every eighteen months to keep pace with developments in the information systems sector of the commercial world). Several enhanced roles for M&S in support of this new model were identified. These included support to Analyses of Alternatives (AoAs) in Concept & Technology Development (CDT), Early Operational Assessments (EOAs) in System Development & Demonstration (SDD), and Operational Test & Evaluation (OT&E) in Production & Deployment (P&D).

However, it was acknowledged that there are several major residual challenges in DoDD 5000 that require future action, particularly in the guidance it provides on system-of-systems acquisition. For example, since individual systems are acquired asynchronously, how do you do "full system demonstration" before the commitment to production or perform T&E of a full system-of-systems? In addition how do you deal with interoperability and supportability of a C4ISR system when multiple configurations are deployed, simultaneously? This latter issue is of particular concern to the US Army that must deal with the simultaneous fielding of large numbers of legacy, interim, and objective systems. As noted in Section B.1.4 of this paper, since the workshop was completed there has been renewed interest in revising the DoDD 5000 series to enable an acquisition policy environment that fosters efficiency, creativity, and innovation. Efforts to achieve those objectives are currently underway.

In the final segment of the plenary, representatives from the three Services described key initiatives. The Electronic Systems Command, US Air Force, is developing a Joint Synthetic Battlespace (JSB) to support the future acquisition and integration of C4ISR-weapon systems-of-systems. This effort has pursued a "top down" approach, systematically addressing the dimensions of leadership, policy, process, technology, and resources. To take advantage of the extensive investment in M&S environments that have been made, this approach strongly emphasizes Service/industry collaboration.

Second, the US Navy is developing a Naval Collaborative Engineering Environment to support Program Executive Officers (PEOs) and PMs in meeting the Service's integration and interoperability requirements. They have adopted a framework for integrated system evolution that emphasizes the separation of data and a suite of multi-functional tools to support the initial phase of acquisition (e.g., mission capability packages supported by Operational Requirement Documents, Analyses of Alternatives).

Finally, the US Army completed the Service perspectives by describing current thoughts on the C4ISR-weapon system mix for the proposed Future Combat System (FCS) and the tools that are evolving to support the acquisition of that capability. In the latter area, they are creating an arena to evaluate future system concepts drawing on the capabilities developed at the Joint Precision Strike Demonstration (JPSD) and the Joint Virtual Battlespace (JVB). The philosophy is to integrate existing M&S tools and resources from a variety of sources (e.g., US Army Research, Development, and Engineering Centers (RDECs), National Labs) and to augment them via a spiral build to address specific system acquisitions.

Looking across the presentations by the three Services, it is noteworthy that cross-Service collaboration on their activities is ongoing and increasing. Since each Service has employed a different, but complementary, approach to the issue, such collaboration has the potential to enhance the quality of each Service's environments and to minimize duplication of efforts. From a system-of-systems standpoint, integrating across the three Services and with coalition partners remains a key challenge.

C.2.2 Break-out Group Insights

Figure 2 provides a framework that identifies a set of M&S-related categories that must be addressed by the acquisition community. The break-out groups concluded that if future C4ISR assessments are to be planned and conducted successfully in a dynamic environment *and* supported effectively by the M&S community, we must consistently address *all* of these factors in a balanced way. The backdrop for these factors is set by the *cultures* of the many communities that must participate in future C4ISR acquisitions. To remind us of the importance of the cultural dimension, one facet of the pyramid is labeled "change in attitude, culture".

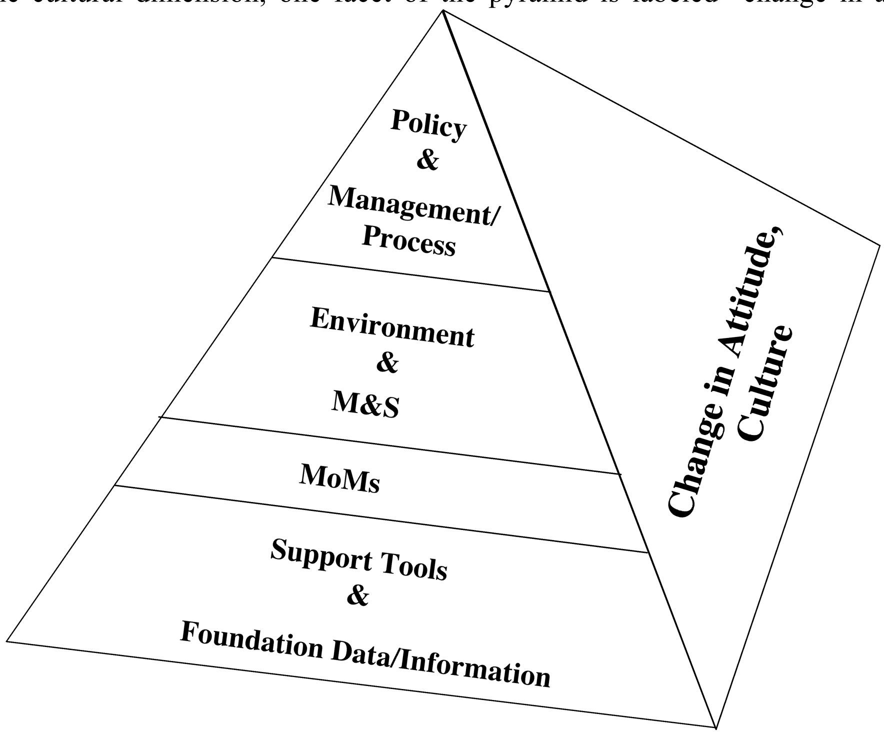

Figure 2. Framework for Recommendations

The base of the framework rests on support tools and foundation data and information. It subsumes repositories of critically needed information (e.g., environmental data). Building on the foundation data/information is a set of broadly needed support tools. These include readily tailorable and reusable scenarios. Resting on these support tools, are sets of hierarchies of measures of merit (MoMs). These range from measures of C4ISR system performance (e.g., bandwidth of communications systems) to overall measures of campaign effectiveness (e.g., the time required to halt an invading army). Once the MoMs have been identified, it serves to clarify the individual M&S modules that are needed to evaluate the measures of interest. These M&S modules are then federated into environments that enable the acquirer to assess the measures efficiently over the requisite set of scenarios and assumptions. In order to develop and employ these environments, it is necessary to have sound policy, management, and associated processes to guide the acquirer in applying M&S appropriately in the acquisition process.

In the area of policy, management and processes, several broad needs were identified. First, the system-of-systems panel called for a revisit of DoDD 5000 to ensure that it addressed critical system-of-systems issues adequately. For example, there was a need to address mission capabilities based decision-making vice individual system decision making. Second, there is a need to develop and provide government/contractor access to authoritative M&S and repositories for data, algorithms, joint scenarios, and synthetic natural environments. Finally, the system-of-systems panel called out the need to derive insights from system-of-systems events (e.g., exercises, experiments). In order to do so, there is a need for sufficient funding, authority, and responsibility to capture and exploit important data from these events.

Each of the panels identified major needs in the area of acquisition environments. The broadest need was articulated by the system-of-systems panel that called out the need for secure, distributed, scalable, responsive, standards-based, collaborative engineering environments. Specific attributes of these environments were identified by the other panels. For example, the C2 panel called out the need for these environments to be interoperable with those of industry and to evolve throughout the acquisition process. The remaining panels noted the need for these environments to be able to interface with other systems, M&S, humans in the loop, and hardware in the loop.

Each of the panels identified major needs in the area of M&S. At a macro-level, the system-of-systems panel called out the need for a reference model for alternative levels of interest (e.g., system, function, mission, campaign) that would help identify key M&S capabilities and shortfalls. Several of the other panels identified specific M&S that were needed. These included communications models appropriate for system-of-system level analyses and network operations support, planning, and training; high level M&S that could support quick turn-around assessments for sensor trade studies; the ability to model information infrastructures; and M&S that featured better representations of decision making processes in C2.

There was general agreement that a hierarchy of MoMs is needed that would support assessments of the impact of C4ISR systems on mission effectiveness. This becomes particularly important in addressing system-of-systems issues, where MoMs are needed which reflect the performance of the system-of-systems capabilities as well as the contribution of individual systems, In the discussion, it was noted that NATO's evolving Code of Best Practice for C2 Assessment (Reference 6) is an excellent point of departure to pursue the development of those MoMs. These analytic constructs are critical if M&S is to be an effective tool.

Several panels identified the need for support tools to enhance the ease of use and responsiveness of M&S. In particular, it was stated that there is a need for reusable, tailorable scenarios; a joint library with an extensive scenario set (including Blue force laydowns); and common environmental representations.

Finally, several of the panels identified the need for key foundation data and information. From a system-of-systems perspective, it was observed that there is a need for synchronization points for past, current, and future system performance data. In addition, needs were identified for common standards for inputs to drive models and the identification of architectural data to link architectural representations to executable simulations.

D. Summary

In order to support the acquisition and transformation of C4ISR systems, a clear "bottom line" emerged from these recent initiatives. First, both events emphasized that it is essential that a cultural transformation be undertaken in the acquisition enterprise. This includes strong institutional leadership, the implementation of appropriate incentives, and the institutionalization of an effective education and training effort. Second, it was concluded that a system-of-systems perspective is vital. It is no longer viable to restrict acquisition to a single system, in isolation. Third, M&S was seen to be a critical enabler of the acquisition process. In particular, a strong, integrated M&S capability is required, in two dimensions. The M&S capability must support the full life cycle of an individual acquisition (i.e., intra-program) as well as cross-program acquisition (i.e., inter-program). Finally, in order to meet the M&S needs of the acquisition community, a balanced set of M&S initiatives must be pursued. These range from initiatives on creating and making available foundation data/information through the formulation of revised high level policy governing system-of-systems acquisition.

As a consequence of these events, preliminary plans for M&S investments to support C4ISR acquisitions are emerging. There is interest in pursuing a range of initiatives including a study of the tools needed to assess proposed operational, system, and technical architectural products, an assessment of existing and emerging M&S applications to support SBA, an assessment of the state-of-the-practice in integrated M&S environments, and, ultimately, an application of these tools and techniques to the evolving operational and systems concepts for network centric warfare.

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Polish Federation of Land Battle in a Distributed Interactive Environment

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ABSTRACT

Polish distributed and interactive environment for training of combat or peace support operations is presented. As a starting point in modelling process a specific theoretical game is considered. Game theory offers good "language of conflict". So we define military conflict game in general sense and transit it to the next phases of modelling – combat process model, decision model, and simulation model. The distribution of conflict model components is natural and results from the real system's component distribution. The generic model of combat process as a multivariate stochastic process is concerned. The transition between the stochastic model and simulation model is shown. The global decision problem is formulated for each side as a stochastic programming problem with many criteria. The main conclusion of the theoretical analysis is the decision variable in such complex situation there is a decision rule and the criterion can be considered as a risk function, defined on the basis of predicted losses. However, real decision process seems to be far from optimal solution, we should indicate the direction of improvement.

Each component of the battle system is described as an object, which has many attributes. The objects' behaviour during the gaming is represented as a simulation process. The local conflict models with input data determined are applied for particular analyses of decisions considered by players. The system components' distribution, communication and synchronisation mechanisms are presented. A prototype of the system so called MSCombat is constructed. The environment proposed is built as an opened system on the basis of formal model and can be developed and improved. The first approach to the distributed communication and computational problem was on the basis of CORBA. The evolution of the prototype from the aggregation of combat models and simplification of land battle to more sophisticated and professional simulation system for CAX is concerned.

The second version of MSCombat was built as a federation according to FEDEP. The different RTIs (DMSO 1.3. NG, pRTI) were used to the implementation and compared in the execution process. Polish federation of land battle is constructed with respect to FOM of DiMuNDS 2000, so the possible cooperation is considered. The financial aspect of the simulation environment development is presented as very complicated process of two stage competition. The prototype was the basis of our position in the competition. It enables preparing of proper offer and after winning good concept of professional simulation system for CAX and combat analyses. The cooperation of many experts, teams from different sources due to the final product is concerned.

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INTRODUCTION

The methodology of modelling and interactive simulation of military conflict for computer assisted exercises and decision support systems is presented. The essence of the approach consists in the imitation of military actions in real situations with a feasibility of the decision process effects' observation. A theoretical game is considered as a basic model of a military conflict. The strategies of players are formulated on the basis of a combat process model that is defined as a multivariate stochastic process. The stochastic model expresses the uncertainty in a conflict situation. There exists the possibility of observation of the battlefield and making decisions on the basis of these measurements. Having known the conditional distributions of observed feature in the battlefield, it is possible to determine decision functions and then estimate a strategy. The multistage stochastic optimisation problem is formulated in order to find an estimation of each side, optimal strategy in a military conflict situation. It seems to be impossible to find, in a sense, the optimal solution in the general formulation (23), (25), so we propose a specific way of generating trajectories of stochastic combat process taking into account decisions made during a military operation. The prototype of an interactive simulator for the combat process analysis was built on the basis of the multivariate stochastic process. The constraint sets and solutions of the stochastic optimisation problem are determined during the simulation running. Each component of the battle system is described as an object, which has got many attributes. The object behaviour during the game is represented as a simulation process. The models of local conflicts with input data determined by players or decision procedures are applied for particular analyses. The combat models for local clashes are implemented. There are two points of view to the modelling. First of all there is decision support in real conflicts, secondly there is a training of decision-makers in conflict situations. So we should take into account in the modelling process the following conditions: dynamics, uncertainty, uncompleted information, human interactions, surprise, counteractions, counter-counteractions and so on. As a starting point in modelling process a specific theoretical game is considered. Game theory offers good "language of conflict". So we define military conflict game in general sense and transit it to the next phases of modelling – battle process model, decision model, and simulation model. The distribution of conflict model components is natural and results from the real system's component distribution. It is very interested, how to reflect the real combat process with respect the decisions made by sides of conflict. How to design such infrastructure which enables proper and effective training of commanders or deep analysis of real conflict. Having a prototype allows us to analyse many performance measures connected with distributed simulation environment and thus to use these results in designing process of professional simulation system for CAX.

NON-COALITION GAME UNDER UNCERTAINTY CONDITIONS

Let us consider the four-person game:

$$\Gamma^{w} =< \{1,2,3,4\}, \{S_{k}^{w}\}_{k\in\{1,2,3,4\}}, \{H_{k}^{w}\}_{k\in\{1,3,4\}} >, \tag{1}$$

which represents a military conflict with peacekeeping forces contribution. The first and the third players represent opposite fighting sides, the fourth player represents the peacekeeping forces and the second player represents the nature (in wide sense a battlefield: battle space, weather, random results of duels and gun fire,...), S_k^w *(k=1,2,3,4)* denotes a set of strategies of player *k*, and H_k^w – payoff function of player *k* (*k*=1,3,4). If peacekeeping forces support one of the conflict side then we have the situation with three players (Najgebauer 1999a).

The strategies of player number one and three are their plans of fighting (movement, fire allocation) and strategy of player four is plan of peacekeeping operations. The strategies of the nature are represented by states of the nature. However, it is difficult to say about payoffs for the nature in a game situation.

Decisions of sides depend on the nature state observed by them. For real state of the nature $\Theta \in \Omega$, where Ω – set of nature states, the game situation can be formulated as follows:

$$s^w = (s_1^w, \Theta, s_3^w, s_4^w), \quad s_1^w \in S_1^w, \Theta \in \Omega, s_3^w \in S_3^w, s_4^w \in S_4^w \tag{2}$$

and the payoff function for players 1, 3 and 4 :

$$H_k^w : S_1^w \times \Omega \times S_3^w \times S_4^w \to R,\ k = 1,3,4 \tag{3}$$

In real situations the decision-makers do not know actual state of the nature and decisions of the enemy, so they realise the observation process of the nature state. We can assume, that they observe random variables Φ_k (k=1,3,4), which have distributions dependent on state Θ. The conditional distribution of random variable Φ_k is denoted by $F(\phi^k|\Theta)$. The set of possible n-component samples can be described as the sample space $\widetilde{\mathbf{\Phi}}_k$ of player k. We can define decision rules as follows:

Definition 1.

Function $d^k(\phi^k)$, defined by:

$$\begin{aligned} &d^k : \widetilde{\mathbf{\Phi}}_k \to S_k^w, k \in \{1,3,4\}, \\ &\phi^k \in \widetilde{\mathbf{\Phi}}_k, s_k^w \in S_k^w, k \in \{1,3,4\}, \\ &d^k(\phi^k) = s_k^w,\ k \in \{1,3,4\}. \end{aligned} \tag{4}$$

we denotes as non-randomised decision function of the player k.

The set of all decision functions d^k is denoted by D_k (k=1,3,4). The payoff function of the player k is a random variable for a given state of nature because it depends on the state and the values $d^1(\Phi_1)$, $d^3(\Phi_3)$, $d^4(\Phi_4)$, where Φ_1, Φ_3, Φ_4 are random vectors with conditional distributions $F_1(\phi^1|\Theta)$, $F_3(\phi^3|\Theta)$, and $F_4(\phi^4|\Theta)$ respectively. So we propose a new payoff function:

$$\widetilde{H}_k^w : D_1 \times \Omega \times D_3 \times D_4 \to R \tag{5}$$

which can be a parameter for random payoff function (3). The "least safe" parameter, under the military conflict conditions, is the expected value of H_k^w :

$$\begin{aligned} &\widetilde{H}_k^w(d^1, \Theta, d^3, d^4) = E_\Theta H_k^w(d^1(\Phi_k), \Theta, d^3(\Phi_k), d^4(\Phi_k)) = \\ &= \int_{\Phi_k} H_k^w(d^1(\Phi_k), \Theta, d^3(\Phi_k), d^4(\Phi_k)) dF_k(\phi^k \mid \Theta) \end{aligned} \tag{6}$$

It is possible to determine the variance of H_k^w and then the new payoff function will be two-dimensional.

The other way is to determine a quantile $\widetilde{h}_{q_k}^w$ of the distribution of variable H_k^w ($q_k \in [0,1]$):

$$\begin{aligned} \widetilde{h}_{q_k}^w = \inf\{h_{q_k}^w : &P(H_k^w(d^1(\Phi_1), \Theta, d^3(\Phi_3), d^4(\Phi_4)) \le h_{q_k}^w) \ge q_k \text{ and} \\ &P(d^1(\Phi_1), \Theta, d^3(\Phi_3), d^4(\Phi_4)) \ge h_{q_k}^w) \ge 1 - q_k\} \end{aligned} \tag{7}$$

and then

$$\widetilde{H}_k^w(d^1, \Theta, d^3, d^4) = \widetilde{h}_{q_k}^w.$$

So we can define the relaxation of game (1) for military conflict:

$$\tilde{\Gamma}^{w} =< \{1,2,3,4\}, \{D_1, \Omega, D_3, D_4\}, \{\tilde{h}^{w}_{q_k}\}_{k\in\{1,3,4\}} > \qquad (8)$$

If we reduce the number of the players in the game (8), we will obtain the game:

$$\tilde{\Gamma}^{w'} =< \{1,2\}, \{D_1, \Omega\}, \{\tilde{h}^{w}_{q_1}\} > \qquad (9)$$

which can represent a model of disaster, where D_1 denotes a set of decision rules of anti-crisis centre (player 1), and the set Ω describes nature states (player 2) as destroy process states, analogously to the combat process.

MATHEMATICAL MODEL OF COMBAT PROCESS

The presented model of battle process is considered from the decision point of view. We would like to present system's model with significant components and possible relations between them. The information is aggregated in the description to better take into account the whole process by the decision-maker. Three sides are proposed (A, B, C), where A, B represent the opposite sides and C represents peacekeeping allied forces.

Let $\{S(t), t \in [0,T]\}$ be the multidimensional stochastic process (Najgebauer 1999a), where:

$$\{S(t) = (S_{1Y}(t), S_{2Y}(t), S_{3Y}(t), S_{4Y}(t), S_{5Y}(t), S_{6Y}(t), S_{1PW}(t), S_{2PW}(t)), t \in [0,T], Y = A,B,C\}, \qquad (10)$$

- $S_{1Y}(t)$ – state of land fighting units of side Y (A, B or C) (command structure, state of readiness, current mission, region, where the side Y units are located, average velocity of the units, number of combatants, the level of training, morale, state of weapon, state of munitions and fuel, level of pollution),
- $S_{2Y}(t)$ – state of supporting units of side Y, (artillery and air forces), (analogously to fighting units),
- $S_{3Y}(t)$ – state of engineering units, (like above and state of engineering equipment),
- $S_{4Y}(t)$ – state of logistics system, (state of supplying bases, transportation system, infrastructure, renewal system, medical system),
- $S_{5Y}(t)$ – state of command and communication system, (state of communication nodes, state of communication net, state of command units),
- $S_{6Y}(t)$ – state of surveillance and electronic warfare units,
- $S_{1PW}(t)$ - state of terrain (cover , vegetation, industry, roads, buildings, fortification, engineering activities).

  The terrain model is discrete and can be expressed as follows:

  $Z=< G, \{\varphi_l\}_{l=1,2,4}, \{\varnothing\}>$,

  where $G =<W,U>$- Berge graph, W – set of vertices , U – set of arcs , $U \subset W\times W$

  φ_1: $W\rightarrow C$ – function, which describes a location of the zone, represented by vertex $w\in W$, (rectangle 200m x 200m) $C\subset R^3$, C describes the whole battlefield area of the conflict,

  φ_2: $W\rightarrow 2^L$ function, which describes an assignment of roads to node w (these roads are accessible for mobility in a zone w), L- set of all road numbers in a battlefield,

φ_3: W × $J^{A(B,C)} \rightarrow 2^{TU}$ – assignment function of formation type subset to node w, TU – set of all possible types of combat units formation,

φ_4: W × $J^{A(B,C)} \rightarrow R^n$ – the determination of maximal velocities of combat units on roads of battlefield, n=|L|.

Arcs of the graph represent possibility of close transition between zones.

- $S_{2PW}(t)$ – state of environment – weather, electromagnetic situation, pollution situation at the moment t,

The process is discrete in states and continuous in time. The transitions between states are caused by combat actions, decisions and their realisations, natural phenomena,....

Each element of the battle system, which represents one of the sides or the battlefield, can be represented as an object. The transitions of the combat process are connected with events on the battlefield and their time is random variable. One of the important sources of randomness on the battlefield there are random results of the local clashes. We have proposed many stochastic models of the local conflict in a sense of locality as a closed combat process between two elementary combat units (process of combat units resource destroying).

The models have been recently developed within the confines of researches conducted in Military University of Technology, Cybernetics Faculty. One of them is the simulation combat model with dynamic fire control. It is an attempt of a description of two sides clashes at the battalion level. We assume that the combat is local. It means that combatants lead a direct fire into opponents under optical visibility and under similar terrain and atmospheric conditions. It is obvious that the locality assumption is not always true in the real world. However if we consider that the warfare applies to small formations which naturally operate in a local area, this simplification seems to be acceptable. Additional assumptions are as follows:

1) two sides of a battle A and B are equipped with heterogeneous armament weapons;
2) each of the weapon is characterized by different properties:
    a) p_{rs} – a probability of one shot hit by combat mean of type "r" to target s-type. The value of this parameter is not constant and depends on e.g.: a distance between opposing weapon systems, terrain and atmospheric conditions of a battlefield;
    b) λ_r – the fire intensity of r-th type combat mean. The parameter either is not constant and depends on e.g.: a level of logistics supplies (ammunition and fuel), a kind of a unit activity (attack, defence, movement);
    c) α_{rs} – the coefficient which characterizes a resistance of a specific r-type weapon from s-type weapon direct fire. It has a measure of a conditional probability of one shot killing when target has hit;
    d) D_r – the range of a effective fire of a r-type weapon. This parameter limits the specific weapon availability during a battle;

    where

    $r \in \{1,2,...,R\}$, $s \in \{1,2,...,S\}$

    and R, S represent numbers of weapon types for each conflict side (adequately A and B).

3) during the course of a battle there is no possibility of reinforcement (soldiers, ammunition, fuel);
4) the command, control and communication system works properly for both conflict sides.

Generally, the presented combat model describes a warfare like a multistage process of alternate optimal decisions calculation and their simulated realization. The decisions (for both A and B side respectively) apply to combat means allocation and there are determined in each stage of the battle process. The simulation of the decisions' effects for a chosen stage we can describe as a multidimensional stochastic semi-Markov process $\xi(t) = (\xi^A(t), \xi^B(t))$ of DC class (discrete in states and continuous in time). The effects of destroying interactions concern to the current armament.

$$\xi^A(t) = \left[\xi^A_{rs}(t)\right]_{R\times S}, \text{ where}$$

$\xi^A_{rs}(t)$ – represents a number of a r-type weapon of side A which has been allocated to fire to s-type weapon of side B.

THE DECISION PROCESS MODEL

During the modelling process, we take into account combat units as encapsulated objects with their internal structure, power, logistics and command, communication, intelligence subsystems. The operation plan is limited to the land units without special type of warfare like air-force support, artillery support. These components are considered in another way (Najgebauer, 1996) (and are included into the decision support system as tools). The modelling process is presented from one side point of view. The decision models for the rest sides can be analogical.

The terrain is considered as a discrete space. In the decision making process we must observe the battlefield and deviation of required trajectory of the battle process:

$$D(t) = \{D_i^t = <t_{i0,}(w_{i,m}^t, v_{i,m}^t, s_{i,m}^t, x_{i,m}^t, r_{i,m}^t)_{\ i=1,2\ldots,Mi^t} > i \in J^A\} \quad (11)$$

where

t_{i0} – start of action for *ith* combat unit,

$w_{i,m}^t$ – vertex of the net $\boldsymbol{Z}$, it is m^{th} vertex on the path, $v_{i,k}^{t}$ – i^{th} unit velocity on the m^{th} vertex, $s_{i,m}^t$ – formation type on the m^{th} vertex,

$x_{im}^t = (x_{i,k}^t(j))_{j=1,2,\ldots,J}^B$ – allocation of i^{th} unit fire,

$r_{i,m}^t$ – the number of wave, M_i^t – the number of vertices on the i^{th} unit path.

There are physical and tactical limits for a decision, which determine constrained set in a moment *t.*

$D^{A(B,C)}(t) \in \Delta^{A(B,C)}(t)$

The General Structure of Decision-Making Process

The whole decision process can be presented as follows:

Determining General Mission as a required subset of states of combat process $S_{sat}(T)\subset X$,

Measuring combat process state at the moment *t* (surveillance subsystem) – *n*-component sample $\xi = (\xi_1, \xi_1, \xi_1 \ldots \xi_n) \in \Xi_t$

Choice of the decision procedure:

g: $\Xi_t \rightarrow \Delta^A(t)$, $\xi \in \Xi_t$, $D(t) \in \Delta^A(t)$, $g(\xi) = D(t)$, which extremises the decision-maker utility function χ, e.g. mean value of losses of side A or probability of event, that state of side A in T it is not far from $S_{sat}(T)$ than d^*

The next step (measuring....)

There are many guidelines for the commander, which must work out his decision. Let us consider a characteristic of combat process:

$$W_n(t, T^A, D^A(t), D^B(t), D^C(t), \mathbf{Q}^Y) \tag{12}$$

Let us assume, that we can determine the conditional distribution of the characteristic:

$$\begin{aligned} &P\{W_n(t, T^A, D^A(t), D^B(t), D^C(t), \mathbf{Q}^Y) < w / S(t) = s\} = \\ &= F_{W_n/S(t)}(w/s; t, T^A, D^A(t), D^B(t), D^C(t), \mathbf{Q}^{\mathbf{A}}) \end{aligned}, \tag{13}$$

where $t, T^A, D^A(t), D^B(t), D^C(t), \mathbf{Q}^{\mathbf{A}}$ there are parameters of combat process. Especially the decisions D^A, D^B, D^C can control of the combat process transitions.

Some of them can be as follows:

F1 – the difference of mission time realisation and mission complete planned on the higher level

$\varsigma_i^t, \partial^t : \Omega \rightarrow \mathbf{R}, i \in \mathbf{J}^A,$

$\partial^t = \max_{i \in J^A} |\varsigma_i^t - T^A|$

$$\begin{aligned} &F_1 : [t, T]^2 \times \mathbf{\Delta}^A(t) \times \mathbf{X} \times \mathbf{\Delta}^B(t) \times \mathbf{\Delta}^C(t) \times \mathbf{Q}^A \rightarrow \mathbf{R} \\ &F_1(t, T^A, D^A(t), s, D^B(t), D^C(t), \mathbf{Q}^A) = \\ &= \theta^t(\partial^t(t, T^A, D^A(t), D^B(t), D^C(t), \mathbf{Q}^A) / S(t) = s) \end{aligned} \tag{14}$$

θ – parameter of random variable ∂^t- it means the biggest difference between termination time of combat units and time, which is determined for the side. The set of parameters $\mathbf{Q}^{\mathbf{A}}$ is given.

$D^A(t) \in \mathbf{\Delta}^A(t), S(t) \in \mathbf{X}, D^B(t) \in \mathbf{\Delta}^B(t), D^C(t) \in \mathbf{\Delta}^C(t)$

F_2 – the losses after the completion of mission:

$$\begin{aligned} &O^t : [t, T] \times \Omega \rightarrow \mathbf{R}, \\ &O^t(T^A) = S_{1A}(t) - S_{1A}(T^A). \end{aligned} \tag{15}$$

$$\begin{aligned} &F_2 : [t, T]^2 \times \mathbf{\Delta}^A(t) \times \mathbf{X} \times \mathbf{\Delta}^B(t) \times \mathbf{\Delta}^C(t) \times \mathbf{Q}^{\mathbf{A}} \rightarrow \mathbf{R} \\ &F_2(t, T^A, D^A(t), s, D^B(t), D^C(t), \mathbf{Q}^{\mathbf{A}}) = \\ &= \Theta^t(O^t(t, T^A, D^A(t), D^B(t), D^C(t), \mathbf{Q}^{\mathbf{A}}) / S(t) = s) \end{aligned}$$

F_3 – the degree of the mission completion

$$\begin{aligned}&R_t^A:[t,T]\times\Omega\to\mathbf{R}\\&F_3:[t,T]^2\times\mathbf{\Delta}^A(t)\times\mathbf{X}\times\mathbf{\Delta}^B(t)\times\mathbf{\Delta}^C(t)\times\mathbf{Q}^{\mathbf{A}}\to\mathbf{R}\\&F_3(t,T^A,D^A(t),s,D^B(t),D^C(t),\mathbf{Q}^{\mathbf{A}})=\\&\beta^t(R_t^A((t,T^A,D^A(t),D^B(t),D^C(t),\mathbf{Q}^{\mathbf{A}})/S(t)=s)\end{aligned}\tag{16}$$

$$R_t^A(T^A)=\frac{(\sum_{m=1}^{M^A}\left|S_{0m}^A-S_m^A(T^A)\right|^p)^{\frac{1}{p}}}{(\sum_{m=1}^{M^B}\left|S_{0m}^B-S_m^B(T^A)\right|^p)^{\frac{1}{p}}},\ p\geq 1\tag{17}$$

$$R_t^C(T^C)=(\sum_{m=1}^{M^C}\left|S_{0m}^C-S_m^C(T^C)\right|^p)^{\frac{1}{p}},\ p\geq 1$$

F_4 – the possibility of actions at the moment τ

$Y_t^A:[t,T]\times\Omega\to\{0,1\}$

$F_4:[t,T]^2\times\mathbf{\Delta}^A(t)\times\mathbf{X}\times\mathbf{\Delta}^B(t)\times\mathbf{\Delta}^C(t)\times\mathbf{Q}^A\to(0,1)$

$$\begin{aligned}&F_4(t,\tau,D^A(t),s,D^B(t),D^C(t),\mathbf{Q}^{\mathbf{t}})=\\&=\varepsilon_t^A(Y_t^A(t,\tau,D^A(t),D^B(t),D^C(t),\mathbf{Q}^{\mathbf{t}})/S(t)=s)\end{aligned}\tag{18}$$

$$Y_t^A(\tau,D^A(t),S(t),D^B(t),D^C(t))=\begin{cases}1,\text{ where } S^{\mathrm{A}}(\tau)\in\boldsymbol{S}_{\mathrm{Act}}^{\mathrm{A}},\ \tau\in[t,T]\\0,\text{ where } S^{\mathrm{A}}(\tau)\notin\boldsymbol{S}_{\mathrm{Act}}^{\mathrm{A}},\ \tau\in[t,T]\end{cases}\tag{19}$$

ε_t^A – the parameter of conditional distribution of random variable Y^A.

Other criteria are possible.

Let us introduce the risk function to assess the decision process. We can use the description of general characteristics of combat process (10) and its expected value or position parameter (e.g. quantile):

$$\begin{aligned}&E(W_n(t,T^A,g^A(\Xi_t^A),D^B(t),D^C(t))\,|\,\Xi_t^A=\xi_t^A,S(t)=s)=\\&\hbar(\xi_t^A,s)=L^A(t,T^A,g^A(\xi_t^A),s,D^B(t),D^C(t))\end{aligned}\tag{20}$$

where $g^{\mathrm{A}}(\xi_{\mathrm{t}}^{\mathrm{A}})=D^{\mathrm{A}}(t)$,

The risk function can be define:

$$\chi^A\!:\ [t,T]^2\times\boldsymbol{G}^A\times\boldsymbol{X}\times\varDelta^B(t)\times\varDelta^C(t)\to\mathbf{R}^2\tag{21}$$

$$\begin{aligned}&\chi^A(t,T^A,g^A,s,D^B(t),D^C(t))=\\&=(E(L^A(t,T^A,g^A(\Xi_t^A),S(t),D^B(t),D^C(t))\,|\,S(t)=s),\\&Var(L^A(t,T^A,g^A(\Xi_t^A),S(t),D^B(t),D^C(t))\,|\,S(t)=s))\end{aligned}$$

or $$\chi^{\mathrm{A}}\!:\ [\mathrm{t},\mathrm{T}]^2\times\mathbf{G}^{\mathrm{A}}\times\mathbf{X}\times\Delta^{\mathrm{B}}(\mathrm{t})\times\Delta^{\mathrm{C}}(\mathrm{t})\times\mathbf{Q}^{\mathbf{A}}\to\mathbf{R}^{\mathrm{k}}\tag{22}$$

where $k \geq 1$,

$$
\begin{aligned}
&\chi^A(t,T^A,g^A,s,D^B(t),D^C(t)) = (\widetilde{f}_k)_{k\geq 1},\\
&\text{where:}\\
&\widetilde{f}_k = \inf\{f_k : P\{F_k(t,T^A,g^A(\Xi_t^A),S(t),D^B(t),D^C(t)) \leq f_k \mid\\
&S(t)=s\} \geq q_k, \text{ and}\\
&P\{F_k(t,T^A,g^A(\Xi_t^A),S(t),D^B(t),D^C(t)) \geq f_k \mid S(t)=s\} \geq 1-q_k\},\\
&S(t)\in \mathbf{X},\ q_k \in \mathbf{Q}^{\mathbf{A}} \text{ is given}\\
&\text{if } \xi_t^A \text{ is a realisation of } \Xi_t^A, \text{ then}\\
&D^A(t) = g^A(\xi_t^A),\\
&t\in[0,T^A], F_k \quad \text{see. (2.15 - 2.20).}
\end{aligned}
$$

$\mathbf{G^A}$ – the set of decision procedures of the side A decision-maker.

The first formulation of decision problem could be one-criterion:

Stage 1. An observation Ξ_t (the distribution: $F(\xi_t^A / S(t), D^B(t), D^C(t))$ is determined),

Stage 2.

a) Find the decision function g^A, which minimise the maximal risk:

$$
\begin{aligned}
&\max_{\mathbf{X}\times\Delta^B}(\chi^A(t,T^A,g_0^A,S(t),g^B,g^C)) =\\
&= \min_{g^A\in G^A} \max_{X\times\Delta^B(t)\times\Delta^C(t)}(\chi^A(t,T^A,g^A,S(t),D^B(t),D^C(t)))
\end{aligned}
\tag{23}
$$

Determine a decision $D^A(t)=g_0^A(\xi_t^A)$, under conditions:

$$D^A(t) \in \Delta^A(t),\ S(t) \in \boldsymbol{X},\ D^B(t) \in \Delta^B(t),\ D^C(t) \in \Delta^C(t)$$

b) Observation of battle state Ξ_t at the following moments $t+\eta, t+2\eta, \ldots$

$$\text{If } \Delta S(t+n^*\eta) \geq \Delta^{gr}S(t+n^*\eta), \text{ then } t:=t+n^*\eta \tag{24}$$

where

$\Delta S(t+n\eta) = (\sum_{m=1}^{|X|}\left|S_m(t+n\eta)-S_m^{DA}(t+n\eta)\right|^p)^{\frac{1}{p}}, p\geq 1$, for p = ∞, $\Delta S(t+n\eta) = \max_{m=1,\ldots,|X|}\left|S_m(t+n\eta)-S_m^{DA}(t+n\eta)\right|$,

go to stage 1

The multiple criteria formulation:

$$
\begin{aligned}
&\chi^A(t,T^A,g^A,s,D^B(t),D^C(t)) = (\widetilde{f}_1,\widetilde{f}_2,\widetilde{f}_3,\widetilde{f}_4),\\
&\text{where}\\
&\widetilde{f}_1 = \inf\{f_1 : P\{F_1(t,T^A,g^A(\Xi_t\ ),S(t),D^B(t),D^C(t)) \leq f_1 \mid S(t)=s\} \geq q_1,\\
&\text{and } P\{F_1(t,T^A,g^A(\Xi_t^A),S(t),D^B(t),D^C(t)) \geq f_1 \mid S(t)=s\} \geq 1-q_1\},\\
&\widetilde{f}_2 = \inf\{f_2 : P\{F_2(t,T^A,g^A(\Xi_t\ ),S(t\ ),D^B(t),D^C(t)) \leq f_2 \mid S(t)=s\} \geq q_2,
\end{aligned}
\tag{25}
$$

and $P\{F_2(t,T^A,g^A(\Xi_t^A),S(t),D^B(t),D^C(t))\geq f_2 \mid S(t)=s\}\geq 1-q_2\}$

$\widetilde{f}_3=\inf\{f_3 : P\{F_3(t,T^A,g^A(\Xi_t),S(t),D^B(t),D^C(t))\leq f_3 \mid S(t)=s\}\geq q_3,$

and $P\{F_3(t,T^A,g^A(\Xi_t^A),S(t),D^B(t),D^C(t))\geq f_3 \mid S(t)=s\}\geq 1-q_3\}$

$\widetilde{f}_4=\inf\{f_4 : P\{F_4(t,T^A,g^A(\Xi_t\ ),S(t),D^B(t),D^C(t))\leq f_4 \mid S(t)=s\}\geq q_4,$

and $P\{F_4(t,T^A,g^A(\Xi_t^A),S(t),D^B(t),D^C(t))\geq f_4 \mid S(t)=s\}\geq 1-q_4\},$

$S(t)\in \mathbf{X},\ q_1,q_2,q_3,q_4\in \mathbf{Q}^\mathbf{A}$ are given,

if ξ_t realisation of Ξ_t , then

$D^A(t)=g^A(\xi_t)$

Stage 1. An observation Ξ_t (the distribution: $F(\xi_t^A / S(t),D^B(t),D^C(t))$ is determined),

Stage 2.

Find the decision function $g^{A*}\in G_N^{A\leq}$, which belongs to non-dominated set of decision functions:

$$G_N^{A\leq}=\chi^{-1}(Y_N^{G^A\leq}), \qquad (26)$$

$$\text{where } Y_N^{G^A\leq}=\{y\in Y_{\max}^{X\times\Delta^B(t)\times\Delta^C(t)} \mid \neg\exists_{z\in Y_{\max}^{X\times\Delta^B(t)\times\Delta^C(t)}} z\leq y\},$$

and

$$Y_{\max}^{X\times\Delta^B(t)\times\Delta^C(t)}=\{y\in C \mid y_i=\max{}_{X\times\Delta^B(t)\times\Delta^C(t)}(\widetilde{f}_i)\},$$

$$\text{where}: \widetilde{f}_i \text{ like } (2.26), i=1,...,4$$

$$C=\{y\in R^3\times\{0,1\} \mid y=(\widetilde{f}_1,\widetilde{f}_2,\widetilde{f}_3,\widetilde{f}_4)\}$$

Determine a decision $D^A(t)=g^{A*}(\xi_t^A)$, where $g^{A*}\in G_N^{A\leq}$

b) The same operations like in the previous formulation (24).

To solve the problem the simulation method is proposed. It is very important to have a possibility of stochastic process (10) trajectory generation. The parameters of the decision model are estimated during the simulation process. The entrants in the interactive mode during the game determine some of them. The replications of the simulation game many times with the same initial scenario enable the estimation of characteristics of combat process. The formal models of decision and combat process allow the correct analysis of simulations. To estimate the results of local combats we propose the specific models of the situations. These models were implemented in a simulation environment. The construction of the decision model requires the distribution of the simulation execution. Especially three different decision centres are located in different places. The decisions are carried out on the basis of initial scenario, received from main centre, which can represent peacekeeping forces, and then the "common model" is executed. The decision-makers can update their decisions during the simulation running (interaction process), taking into account the previous decisions and observed situation. The reconnaissance model, which is simulated, reflects the possibility of observation for each side. Each of the orders and reports are presented in real CIS (Command Information System) – in Polish system there are in ADatP3 format.

THE ENVIRONMENT FOR COMBAT INTERACTIVE SIMULATION

Federation Design

A generalized process for building HLA federations can be described by FEDEP – a high-level framework for the development and execution of HLA federations. According to FEDEP, we should determine which existing simulation systems are suitable to become members of the federation. But often federates don't exist and we have to develop all federation members. New federates or changes to the existed software design and implementation must be implemented. Using RUP (Rational Unified Process), Rose (a graphical component for modelling and development) and UML a object oriented representation of the federation can be developed: the specification of object classes, attributes, methods, object relationships, interaction classes, and parameters.

The base software package layer of the MSCombat is composed of control package, RTI package, scenario generator package, combat models package and other. The detailed project of The MSCombat contains a set of class diagrams (with attributes, methods and relationships), a set of sequence diagrams, a set of component diagrams and a deployment diagram. For instance Fig. 1. presents the MSCombat software package layer and class diagram of the simulation time manager.

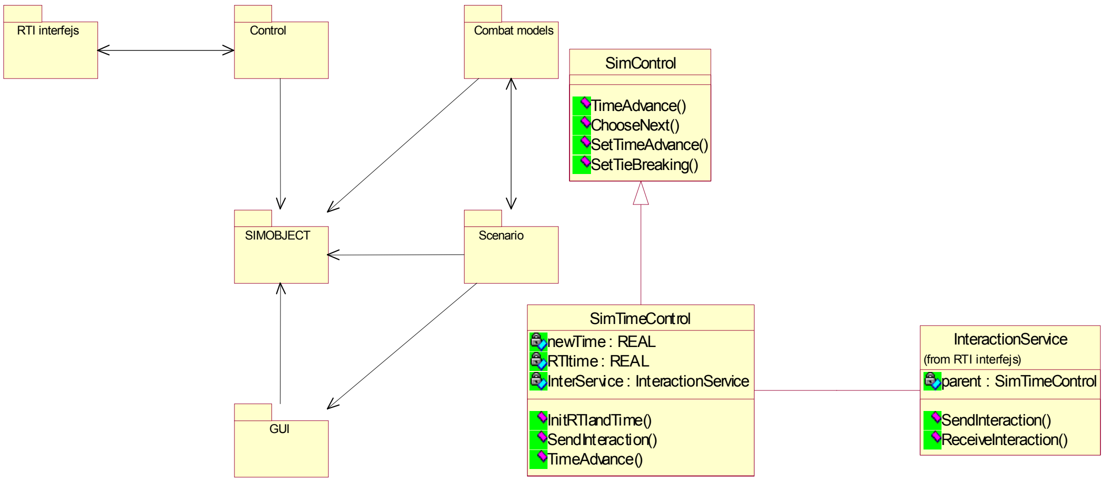


Figure 1: The MSCombat Software Package Layer and an Example of Class Diagram.

During this phase we should allocate the entities and actions from the federation conceptual model to the federates. Moreover technical issues such as time management, federation management can be described at this phase too. In the MSCombat environment a conservative mechanism is implemented but time-step, hybrid or real-time algorithm can be realized in the interactive mode. The RTI software controls global "time flow" and global message ordering.

Federation Development

Main tasks at the current phase is to develop the Federation Object Model (FOM), implement or modify existing federates and prepare the federation for integration and test. In order to create FOM model we can use Object Model Development Tool which provides integrated access to supporting resources and automates the production of the Federation Execution Data (FED) file required by the RTI. The interoperability of MSCombat system is determined by the interactions and objects classes included in FOM file "MSCombat.fed". Each object or interaction class must be represented by adequate class with attributes and methods in a project and then in a software. Rational Rose provides a proprietary scripting language (Rose script) which allows for the importing and exporting of object models. In order to export an OMDT model to Rational Rose we should to:

1) Prepare a FOM model using OMDT.
2) Generate and export the Rose script file (*.ebs).
3) Open the script file in the Rational Rose.
4) Execute that script.
5) Results: several new classes will be added to the current Rose model.

The FOM components that will be exported to the Rose model are classes, attributes, interactions, and parameters. The Rose script rules are:

- the created classes consist of FOM attributes as public;
- interactions are treated differently than attributes – interactions are created as public methods of a class called HLA Interactions, because there are no classes with interactions in the HLA object model.

The methods of the HLA Interactions then should be divided and included into the existing or new the project classes. A class diagram generated from “MSCombat.fed” with described method is presented in Fig. 2.

Figure 2: MSCombat FOM Class Diagram.

The visualization federate was constructed in order to virtual reconnaissance. Its SOM is based on the Aggregate object while other constructive federates use the Unit object and mentioned interactions.

The FOM of a prototype MSCombat has been extended to more complex model which is partly consistent with the DiMuNDS federation object model. A compatibility is achieved on the object, attribute, interaction, parameter name, data type and meaning levels. For example, a part of object classes from a professional simulation system is:

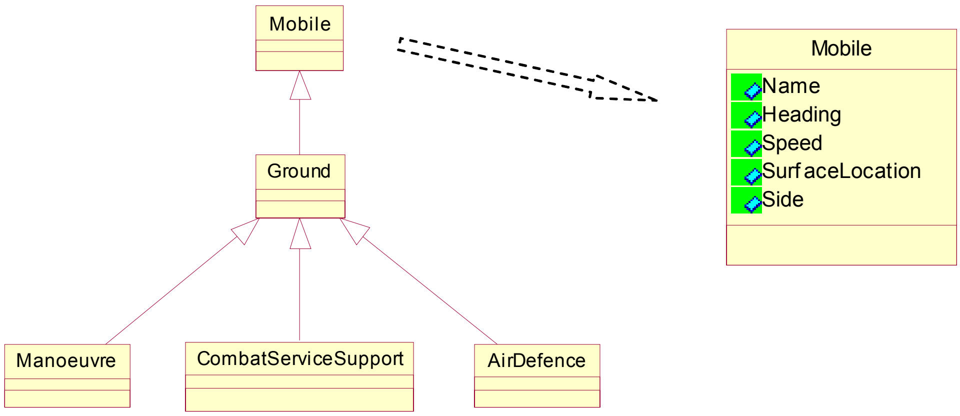
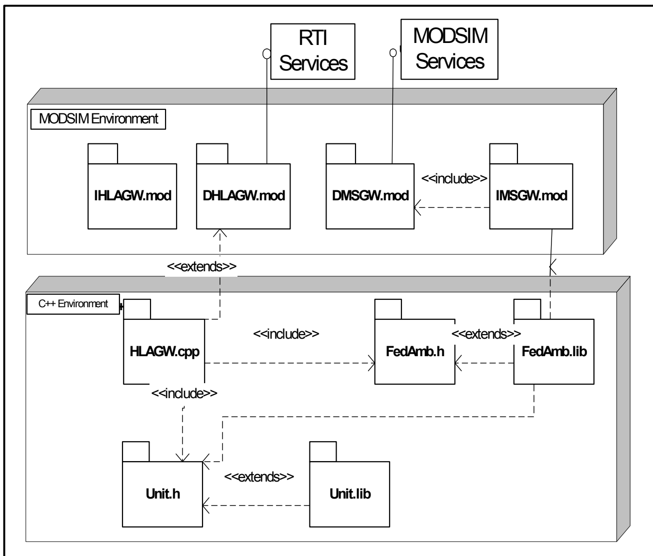


Figure 3: A Part of Extended FOM.

The second task of the phase "Develop Federation" is to implement or modify existing federate software. The MSCombat is build with object-oriented simulation language MODSIM/SIMOBJECT and RTI/HLA API library. The cooperation between Runtime Infrastructure and MODSIM is realized with specific interface, that is built in MSVisual C++ and appended to MODSIM. The interface is composed of many software components, which have to interact according to services called by a user or a program. The functionality of the interface is limited by the set of chosen RTI services to implementation in MODSIM. The most important services implemented as procedures and object methods are listed in Fig. 4.




```
FedAmbObj = OBJECT
ASK METHOD ReceiveInteraction(IN interaction:
STRING; IN message: STRING; IN unitName: STRING;
IN side: STRING; IN xPosition: STRING; IN yPosition:
STRING; IN item: STRING; IN state: STRING; IN time:
REAL);
ASK METHOD ReflectAttributeValue(IN objHandle:
INTEGER; IN attrHandle: INTEGER; IN attrValue:
STRING; IN time: REAL);
ASK METHOD DiscoverObjectInstance(IN objHandle:
INTEGER)
ASK METHOD TurnInteractionOn(IN interaction:
STRING);
ASK METHOD TurnInteractionOff(IN interaction:
STRING);
ASK METHOD ProvideAttributeUpdate(IN objHandle:
INTEGER; IN attrHandle: INTEGER);
……...
END OBJECT;
```

Figure 4: Modsim – HLA Interface.

Federation Integration and Testing

This phase consist of followed tasks:

- Plan the federation execution;
- Establish all required interconnectivity between federates;
- Test federation prior to execution.

There are three levels of testing: federate testing, integration testing and federation testing. In order to finalize this phase we propose the following steps:

- Battle scenario preparing;
- Simulation environment configuration;
- Initial condition input and choosing combat model version;
- Setting monitors of internal and external characteristics;
- Experimentation – battle simulation in a interactive mode;
- Experiment repetition with new models and condition data.
- Analysis results of the experiment series;

We can distinguish two kinds of characteristics: external and internal. The external characteristics derive from modelling process and describe the commander decision process, combat process and other simulation result. The most important characteristics there are: the difference of mission time realisation and mission complete planned on the higher level, the losses after the completion of mission, the degree of the mission completion, the possibility of actions at a moment t. One of specific indicators – combat success indicator:

$$BT(t) = \frac{F_2^A(t) / F_0^A(t)}{F_2^B(t) / F_0^B(t)}$$

where $F_2^A(t)$, $F_2^B(t)$ – the losses of two sides at the moment t and $F_0^A(t)$, $F_0^B(t)$ – combat value of the sides' forces. It is possible to find three situations:

- If BT(t) < 1, then side A is winning,
- If BT(t) = 1,then balance of the battle at the moment t,
- If BT(t) > 1, then side B is winning.

The internal characteristics describe environment performance, service failures, resource usage, workload etc. The most important characteristics there are: two-way latency of TSO interaction sending and receiving, two-way latency of attribute update, latency of ownership acquisition, maximum number of object instance, initialisation time of the whole system. The goal of this benchmark is to provide a general-purpose method to gather latency and throughput performance data for the largest possible number of RTI configurations. The independent variables are: number of objects instances, number of attribute types, object attributes an interaction parameters size, processor clock and available RAM. An example of a test sequence diagram is presented in the Fig. 5.

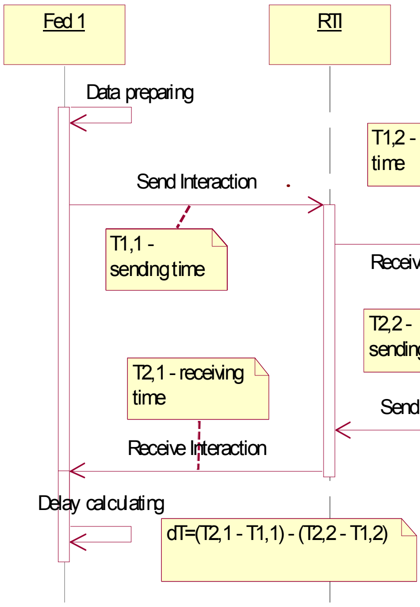


Figure 5: Interaction Latency Test Sequence Diagram.

Execute Federation and Prepare Results

The last phase of The FEDEP is concerned with:

- Execute the federation;
- Process the output data from federation execution;
- Report results;
- Archive reusable federation products.

The deployment diagram of the MSCombat environment is presented on the Fig. 6.

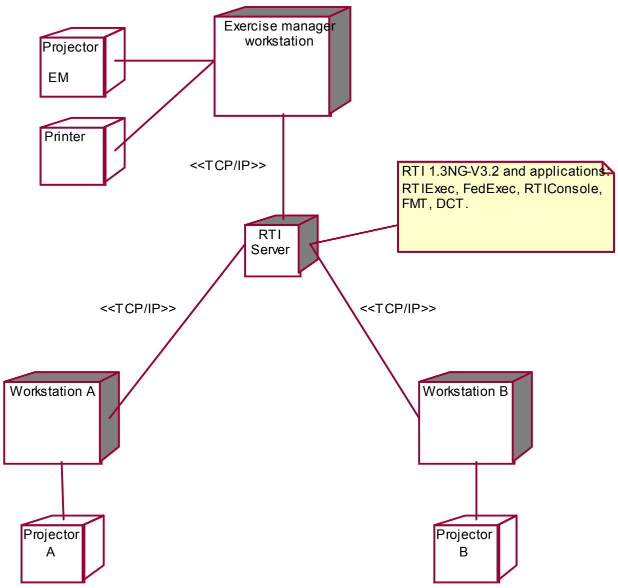


Figure 6: Deployment Diagram of the MSCombat Environment.

An extended version of MSCombat is a professional simulation system environment. It includes:

- a data base server,
- an application server,
- a few sets of terminals (each set for one conflict side),
- a 3D visualization station.

Statistical measures and other data reduction methods are used to transform raw data into derived results. We have used commercial off-the-shelf (COTS) statistical analysis tools SPSS. At the execution phase we have run stand-alone tests on our federate based on two implementations of RTI: DMSO RTI NG 1.3 and commercially available Pitch RTI. It is RTI performance in terms of the rate at which time advance requests are processed. The presented results were obtained in LAN environment. A few instances of the program (the time-regulating and time-constrained federate) were run on local PC (PC 700-2000 MHz, 128-512 MB RAM, Win2000). Each instance was responsible for sending and requesting a the specified number of interactions and collecting statistics on performance.

The example of internal characteristics "The maximum number of object instance" is presented in the Tab. 1 and Fig. 7.

Table 1: Outcomes from Test "The Maximum Number of Object Instance".

# Attributes	# instances (RTI: 256 MB – federate: 128 MB)	# instances (RTI: 256 MB – federate: 256 MB)	# instances (RTI: 128 MB – federate: 256 MB)
1	65536	65536	65536
10	65536	65536	65536
20	60292	61092	63567
30	40423	43025	23301
40	29838	31878	–
50	25135	26126	–
100	13057	13246	15356

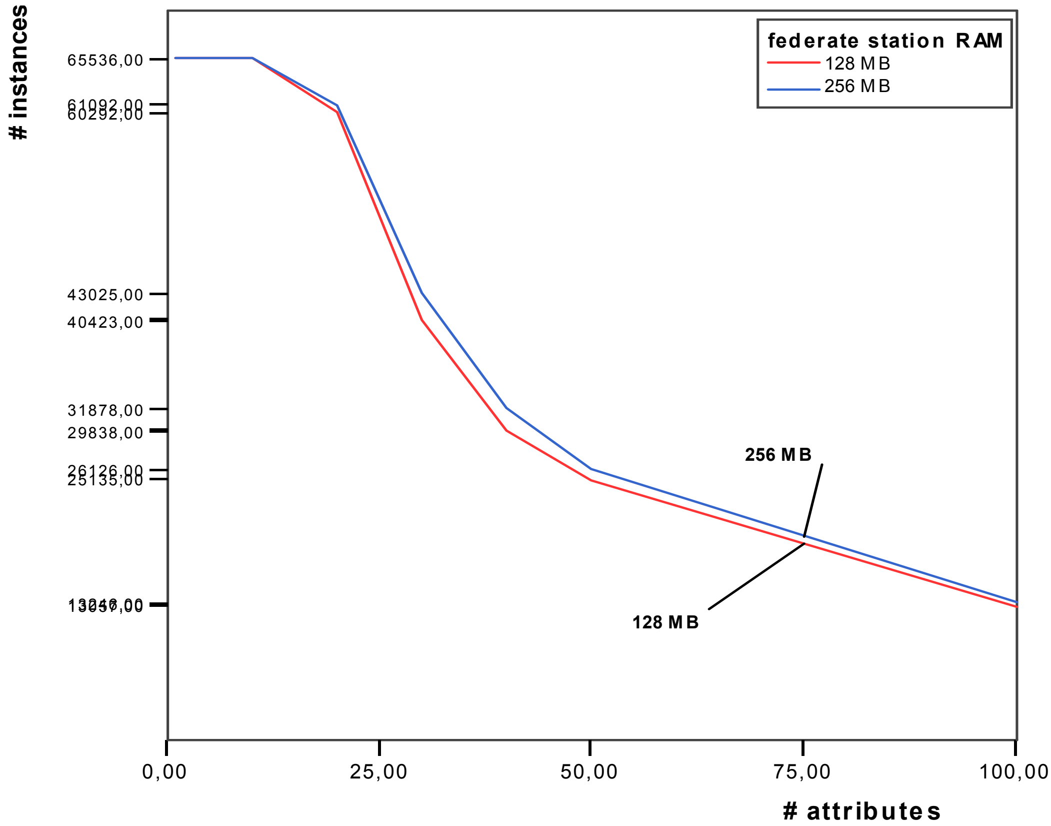


Figure 7: Outcomes from Test "The Maximum Number of Object Instance".

The example of external characteristics "The losses after the completion of mission" is presented in Fig. 8 – the estimation of Red losses can be presented with tendency function fitting.

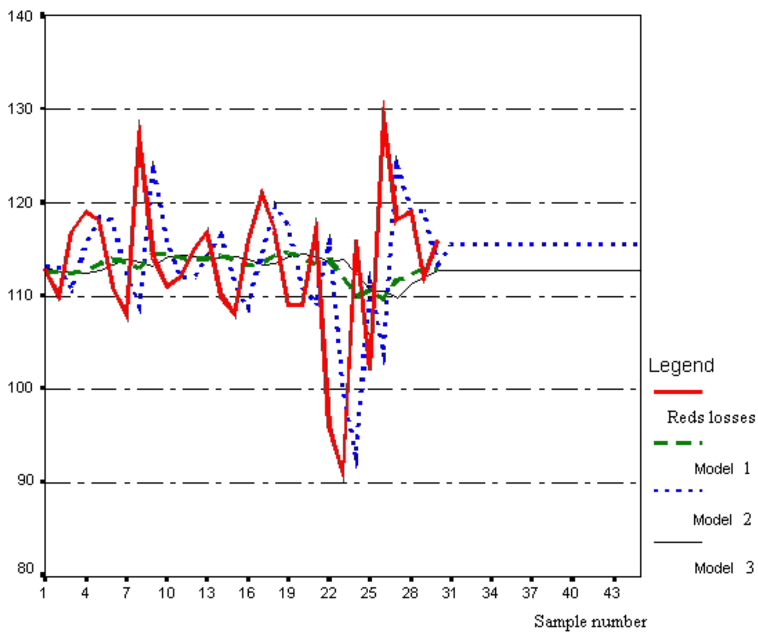


Figure 8: Tally for Trend Models of Red Losses.

CONCLUSIONS

MSCombat is the example of simulator which has been developed for different purposes, but can be used in new simulations thanks to HLA interface. Migration to HLA requires some modification to existing management and engineering processes to capture the benefits offered by HLA. We have verified a development cycle with RUP, UML and FEDEP. We have to make extensive modifications to adapt the simulator so that it can be integrated into a new combined simulation. The performance of the environment with MODSIM/HLA interface is comparable with performance of base RTI environment in the focus of proposed characteristics. The benchmark results are intended to provide assistance to simulator developers in the whole process of HLA federation design, implementation and execution.

The environment proposed is built as an opened system and can be developed and improved – that means there is easy way to include new combat models, unit structures, tactical rules and more monitored characteristics. The characteristics of battle process are being monitored during the simulation process and their statistical analysis allows combat actions predicting for different conflict situations. It should be stressed that approach proposed here requires good knowledge of conflict processes and careful preparation of a conflict scenario. The validation process is very difficult but it is possible to use description of known conflicts and compare with the simulation results. The very interesting direction of further researches there is pattern recognition of decision situation on the basis of simulated actions for example our local combat generator there is something like knowledge base. We try to use virtual reality tools to realize one of important element of combat planning there is reconnaissance of battlefield by commander before the battle.

The important aspects there are financial conditions of the simulation system development. Our experiences indicate one of interesting ways of the realization process by prototype of the system development. MSCombat, which was modelled, designed and developed in our University enabled proper preparation of concept phase and took place in the formal competition, announced by Department of Armament Policy (part of MoD) and finally we have won the project realization.

ACKNOWLEDGEMENTS

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Partnership to Establish the Republic of Uzbekistan Special Center for Modeling and Simulation (SCMS) and National M&S Infrastructure

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BACKGROUND

The Republic of Uzbekistan has embarked upon a very comprehensive and challenging initiative to introduce modeling and simulation (M&S) into its Armed Forces. Minister of Defense of Uzbekistan, Dr. Kodir Gulamov, visited the United States in October 2000 as part of an official United States (US)-Uzbekistan (UZ) series of national discussions. During this visit Dr. Gulamov met with senior members of the US Office of Secretary of Defense (OSD) and shared his vision and desire to introduce M&S into the Uzbek Armed Forces. The lead OSD office for Uzbekistan, OSD International Security Policy (ISP)/Eurasia, contacted the Modeling and Simulation Information Analysis Center (MSIAC) and requested a visit and discussion on M&S and its value to Uzbekistan. Additionally, during the half-day visit, the need for increased M&S awareness and education and, specifically, the need for a national level M&S Master Plan to guide the Uzbek initiative were addressed. After his visit to the US, Minister Gulamov requested OSD assistance in initiating a program to accomplish these specific tasks in order to develop the foundation for the introduction of M&S into the Uzbek Armed Forces. OSD ISP/Eurasia requested that the MSIAC assist them in this effort and arranged for this effort to be initiated with a visit by OSD ISP/Eurasia and MSIAC personnel to the Uzbek Ministry of Defense (MOD) in May 2001.

In May 2001, the two representatives from the MSIAC along with a representative from its OSD sponsor, ISP/Eurasia, traveled to Tashkent, Uzbekistan for a 10-day visit and series of meetings. During this visit, several sessions of M&S education courses were conducted and as well as a weeklong series of meetings to discuss the needs, requirements and concept of this initiative. The Uzbek Armed Forces assembled a large group of people, involved in this initiative, to participate in the M&S education sessions so that all members would have a common understanding of M&S policy, technical and utilization concepts and terms. A senior level-working group was established with key Uzbek Armed Forces leaders and technical experts to work with the US members from the MSIAC. The formation of this working group was, and still is, one of the most critical elements in the success of this partnership project. Minister Gulamov met with the key members of the

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working group, the US Embassy representatives and his International staff and provided his vision and priorities for the introduction of M&S into the Armed Forces of Uzbekistan. He considered this M&S initiative as a key component of his efforts to transform the Uzbek Armed Forces. Minister Gulamov expressed the desire to improve his officers' leadership skills by using M&S in support of that goal. He provided a set of priorities for the introduction of M&S into the Uzbek Armed Forces; 1) M&S at the tactical level (at the Armed Forces Academy simulation center), 2) M&S in support of education and training at the military colleges and sergeants schools, and 3) at the operational level (at the Military Districts). He also stated that he would like to send officers to the US to receive advanced degrees in M&S. Minister Gulamov expressed his support and commitment for this initiative and asked the working group to develop the means to accomplish his vision. Additionally, discussions about the introduction of advanced distributed learning (ADL) were initiated by the Uzbek members of the working group and it was requested that this also be included in the planning effort. During the final working meeting, it was requested that the initial three-year planning effort be completed within a two-year timeframe and this request was approved by OSD. The working group also agreed on a process for development of the required planning documents and the basis for a Terms of Reference (TOR) to guide this effort.

The MSIAC developed the draft of the TOR along with a proposed timeline for the project. This draft was sent to the Uzbek working group for comment and proposed changes. The MSIAC completed the TOR with the Uzbek changes and provided the proposed TOR to OSD ISP/Eurasia for official coordination with the US Embassy in Tashkent, Uzbekistan and the Uzbek MOD. The TOR was signed by all parties and has provided the method and responsibilities for the conduct of the 2-year planning and education project.

MSIAC

The Modeling and Simulation Information Analysis Center (MSIAC) is one of 13 government-owned, contractor-operated information analysis centers under the guidance of the Defense Technical Information Center and sponsored by the Defense Modeling and Simulation office (DMSO). IIT Research Institute (IITRI) operates the MSIAC. The mission of the MSIAC is to be the center for excellence for M&S knowledge and operational support and to provide M&S solutions and services to defense organizations and industry. The members of the MSIAC staff are experienced defense and M&S professionals who understand operational problems, training, education and resources.

The MSIAC was designed to be the single integrated support activity for the use, employment and sustainment of modeling and simulation. It is an independent unbiased organization that can leverage the US defense community's M&S capability to find the most cost-effective solutions. The MSIAC is the focal point for M&S solutions with particular emphasis internationally in the following areas:

- Facilitates the development of integrated, state-of-the-art M&S capability for the Defense Forces; From concept to final product
- Requirements analysis
- Strategic planning and implementation
- Conducts M&S education and training
- Provides access M&S information and assistance

The MSIAC is currently conducting similar strategic planning and implementation assistance efforts in several countries. The MSIAC is a member of the US Enterprise team (ET).

ENTERPRISE TEAM

The US Enterprise team (ET) is a group of US organizations that are working in the international community and have formed a working group to coordinate, share information and assist each other in international activities. This coordination and assistance directly benefits the country in which they are working through the planning and synchronization of all the ongoing US M&S efforts and the implementation of a common approach, structure and hardware that can have multiple uses for the supported country. The current members of the ET and their roles within the ET are as follows:

- **Modeling and Simulation Information Analysis Center (MSIAC)** – Modeling and simulation requirement determination, strategic planning and education
- **Joint Forces Command (JFCOM)** – Global lead for Regional Security Cooperation Network and Joint M&S
- **NAVAIR Training Systems Division (NAVAIR TSD)** – Enhanced International Peacekeeping Capabilities (EIPC) program and Naval M&S
- **Simulation, Training and Instrumentation Command (STRICOM)** – Simulation Center establishment and Army M&S
- **Electronic Systems Center (ESC)** – National Military Command Center (NMCC) and Air Force M&S

MISSION

The mission of the Uzbek Modelling and Simulation Working Group (MSWG) and this initiative is to develop a comprehensive, integrated, state-of-the-art M&S and Advanced Distributed Learning capability for the Uzbek Armed Forces that will significantly improve operational readiness and technical capabilities. The MSWG is lead by the Ministry of Defense (MOD) with representative from the MOD, Military Academy and other parts of the Armed Forces, U.S. Office of the Assistant Secretary of Defense (International Security Policy) (OASD (ISP)) Eurasia, the U.S. Defense Attaché Office (USDAO) in Tashkent, and the U.S. Modeling and Simulation Information and Analysis Center (MSIAC). The MSIAC has brought the power and capabilities of the US ET to assist with this effort in Uzbekistan.

The specific characteristics of this initiative are shown below:

- Eight-year (plus) multi-phased program
- National M&S Center and 18 interconnected distributed facilities
  - Military Colleges, Sergeants Schools, Operational Commands and other Ministries involved with Civil Emergencies
- Integrated Advanced Distributed Learning capability
- NATO/PFP Interoperable
- Detailed coordinated planning and execution
  - Requirements Analysis through M&S Master Plan
- National ability to independently sustain and maintain the M&S system

SCOPE AND VISION OF M&S INITIATIVE

Scope

The scope of this plan covers current, developmental and future M&S and ADL systems. It addresses Uzbek Armed Forces needs in the principal application areas of training and exercises, defense planning and analysis, combat and security operations, military support for civil emergencies, research, technology development, and military equipment acquisition.

Vision

This plan establishes a methodology for the development of simulations in order to foster their interoperability and reuse, lays out a high-level roadmap for acquiring and developing a set of simulations and lays out other actions necessary to ensure the cost-effective development and employment of advanced M&S and ADL technology. It is a living document that will be revised as necessary to accommodate changes in requirements, technology, development strategies, employment concepts, opportunities, etc.

The Armed Forces of the Republic of Uzbekistan will use modelling and simulation, advanced distributed learning and related information technology to improve dramatically the combat readiness and technological capabilities of military personnel. Modeling and simulation and information technology will be integrated into a more robust technological infrastructure that will support military organizations at the tactical, operational, and strategic levels. This infrastructure will provide enhanced capabilities to conduct training and exercises, defense planning and analysis, combat and security operations, military support for civil emergencies, research, technology development, and military equipment acquisition.

Key Goals

The Minister of Defense intends to create an M&S and ADL capability within the Armed Forces and has stated specific goals for introduction of this capability. The Armed Forces plan to accomplish three specific goals through the use of M&S and ADL:

1) Improve efficiency in training military personnel,
2) Improve the professional skills and information-analytical capabilities of commanders and staff at different levels, including the development of threat scenarios,
3) Develop M&S capabilities as part of transformation of the Armed Forces.

Priorities

The Minister of Defense identified four major priorities for introducing M&S and ADL into the Armed Forces:

1) Develop M&S and ADL capabilities in new simulation center at the Academy of the Armed Forces to train personnel attending the Academy,
2) Develop M&S and ADL capabilities at the military colleges where initial-entry officers are trained,
3) Develop M&S and ADL capabilities at the Sergeants Schools,
4) Develop M&S and ADL capabilities at the Military Districts where the operational forces have their major headquarters.

Note: The capabilities outlined above will be added in a phased approach as experience is gained and as resources are made available.

STRATEGIC PLANNING AND IMPLEMENTATION ASSISTANCE

Key to the entire initiative with Uzbekistan has been the partnership between the US and Uzbekistan is developing the documents listed below. The documents and the educational and developmental process conducted to produce these fundamental guiding documents form the basis for the successful implementation of a comprehensive M&S capability within the Republic of Uzbekistan. These documents are:

- Requirements Analysis – Identifies requirements, resources available and existing M&S capability
- Concept Overview – Outlines the proposed M&S Strategy and provides an agreed document on which to base future planning
- Strategic Plan – Provides sufficient detail to support national programming and budgeting decisions
- M&S Master Plan – Foundation of the planning & implementation process – Contains as required:
  - Implementation Strategy
  - Integration Strategy
  - Acquisition Strategy
  - Education Strategy
  - Long-term Strategy

The Master Plan is the foundation of a comprehensive M&S capability. The M&S Master Plan approach has several specific characteristics:

- Tailored to the needs of the Armed Forces
- Action plan, not a study
- Vision, requirements, objectives and time-phased actions
- Detailed implementation, integration, acquisition, education and long-term strategy annexes
- Development process is an iterative and interactive educational process
- Living document – periodically revised to match evolving requirements and changing resources

These M&S capabilities can be acquired and implemented early in the planning process.

REPUBLIC OF UZBEKISTAN MODELING AND SIMULATION (M&S)/ADVANCED DISTRIBUTED LEARNING (ADL) MASTER PLAN

This document outlines a plan for the development of comprehensive modeling and simulation (M&S) and advanced distributed learning (ADL) capabilities for the Armed Forces of the Republic of Uzbekistan. The Ministry of Defense (MOD) initiated this program to facilitate education and training of Armed Forces personnel and to support military operations. This plan outlines the vision, requirements, and objectives. It also provides a time-phased approach for implementing these objectives and identifies the resources required to implement this program successfully.

This M&S/ADL Master Plan (MS/ADL MP) serves as an implementation guide for the Uzbek Armed Forces in the critical areas of modelling and simulation and advanced distributed learning. Subsequent editions of the plan are expected to define further the actions required to enhance M&S and ADL support to Armed Forces operations. In addition, the plan is expected to evolve as the Uzbek Armed Forces proceed with implementation, gain experience and develop additional insights.

The MS/ADL MP:

- Articulates a vision regarding the use of M&S and ADL in furtherance of the mission of the Uzbek Armed Forces;
- Outlines the impact that achieving this vision will have on various aspects of Armed Forces operations;
- Identifies the Armed Forces' M&S and ADL requirements;
- Establishes a strategy and a set of key objectives that the Armed Forces must accomplish to realize its vision and satisfy its M&S and ADL requirements;
- Identifies the actions required to achieve these objectives in a timely and a cost-effective manner; and
- Assigns responsibilities for accomplishment of the plan.

The following are important, but less immediate requirements for M&S and ADL capabilities. These capabilities will be added as expertise is developed and resources are made available.

1) Force Structure Analysis – Force structure analysis is the process of assessing and deciding on the right mix of personnel, material, weapon systems and training to optimise military capabilities. M&S can be useful tools in these assessments, allowing the MOD staff to analyse alternatives while considering various scenarios and force mixes.
2) Military Support For Civil Emergencies – The Armed Forces may provide needed assistance to civil authorities during man-made and natural disasters. M&S and related capabilities can be used to provide situational awareness and develop a coordinated response to such emergencies. For example, M&S applications can be used to analyse the aerial dispersal of contaminants, to predict casualties and allow for prompt evacuation of personnel. ADL capabilities can be used to train personnel in proper response techniques.
3) Research, Technology Development, and Military Equipment Acquisition – The cost effective and efficient development of armaments can be greatly enhanced with the use of M&S. A wide range of M&S applications are available to support concept development, engineering design, system integration, production, logistics and testing of advanced weapon systems.
4) National M&S and ADL Center(s) – The capabilities developed by the Armed Forces may have broader applicability to other government ministries and educational institutions.

M&S/ADL MASTER PLAN OBJECTIVES

The MSWG has developed a set of objectives that must be achieved to establish the M&S, ADL and related information technology capabilities required for this program. These objectives relate to standards, services, communications, facilities, hardware, software, and technological capabilities necessary for successful development and support of comprehensive M&S and ADL capabilities. These capabilities are categorized in the seven objective areas listed below:

Objectives

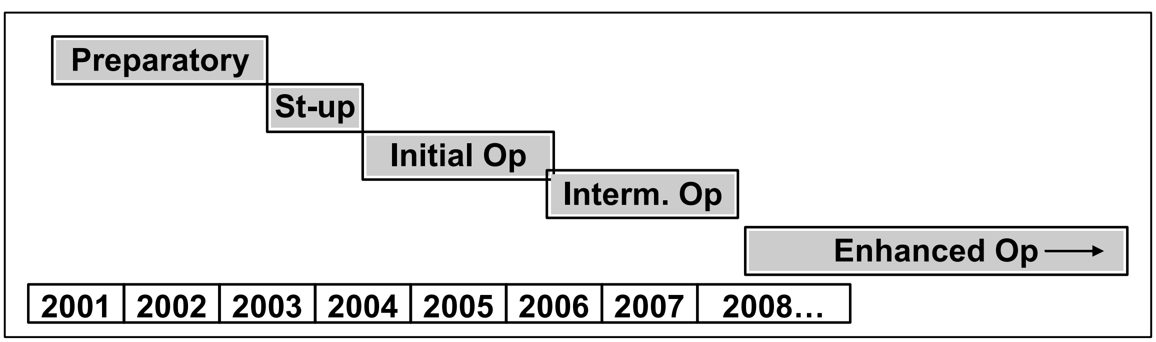
Common Technical Framework	Common Services	Communi-cations and Facilities	Models and Simulations	Operate Simulations	Advanced Technology Knowledge	Advanced Distributed Learning
1.1Standard Simulation Architecture	2.1Simulation Resource Library	3.1 Comm. Infrastructure	4.1 Acquire Models and Simulations	5.1 Technical Support	6.1 Advanced M&S Education	7.1 ADL Standards
1.2 Data Standards	2.2 Central Help Desk	3.2 Facilities	4.2 Develop Models and Simulations	5.2 Data Support	6.2 M&S Knowledge Base	7.2 ADL Communi-cations
	2.3 M&S Configuration Management		4.3 Integrated Systems Engineering	5.3 Operator Training	6.3 International Distributed Simulations Exercises	7.3 Course Development
	2.4 Education and Outreach			5.4 Distributed Simulation Management		7.4 Digital Library

PHASED DEVELOPMENT AND IMPLEMENTATION WITHIN THE UZBEK INITIATIVE

Developing and implementing a comprehensive M&S and ADL program that supports a wide-range of needs will be achieved by the phased development of capabilities. This approach allows the Armed Forces to plan, initiate, and incrementally develop adequate infrastructure in step with prioritized needs. It expands capabilities as personnel gain experience and as resources become available. This section outlines a five-phase implementation strategy that incrementally develops capabilities.

The five phases are shown in the chart below with specific discussion on each phase following:

Implementation Phases



Preparatory

The Preparatory Phase is a two-year planning and organizing time period. During this timeframe, the working group collaboratively develops a Terms of Reference (TOR), conducts a needs analysis, determines requirements and drafts the Concept Overview. Building on the needs analysis, requirements determination and Concept Overview, the M&S and ADL Master Plan, Implementation Plan, Acquisition Strategy, and Future Plan are developed. The Special Center for Modeling and Simulations (SCMS) building modifications are completed and computer equipment is procured. Armed Forces personnel start advanced education programs and attend information exchange programs. This phase started in May 2001 with the first MSWG planning meeting and ends in April 2003 with the completion of planning and preparatory activities.

Start-Up

The Start-up Phase is a one-year period during which the Implementation Plan and Acquisition Strategy are first executed. The SCMS is equipped, systems prepared for use and procedures are refined. The use of simulation in academic instruction at the Academy will be demonstrated in October 2003. In December 2003, the SCMS will be used to allow the Armed Forces of the Republic of Uzbekistan to participate in Viking 03, a Partnership for Peace multinational staff training exercise. This phase begins in May 2003 and ends in April 2004.

Initial Operational

During the Initial Operational Phase the Simulation Center becomes operational and is used for training officers attending the Academy. Participation in joint computer-assisted exercises and similar M&S activities with other nations can be continued in this phase. Planning and coordination development of capabilities at the Military Colleges and Sergeants Schools is completed. This phase begins in May 2004 (or earlier, if start-up activities are completed) and continues through April 2006.

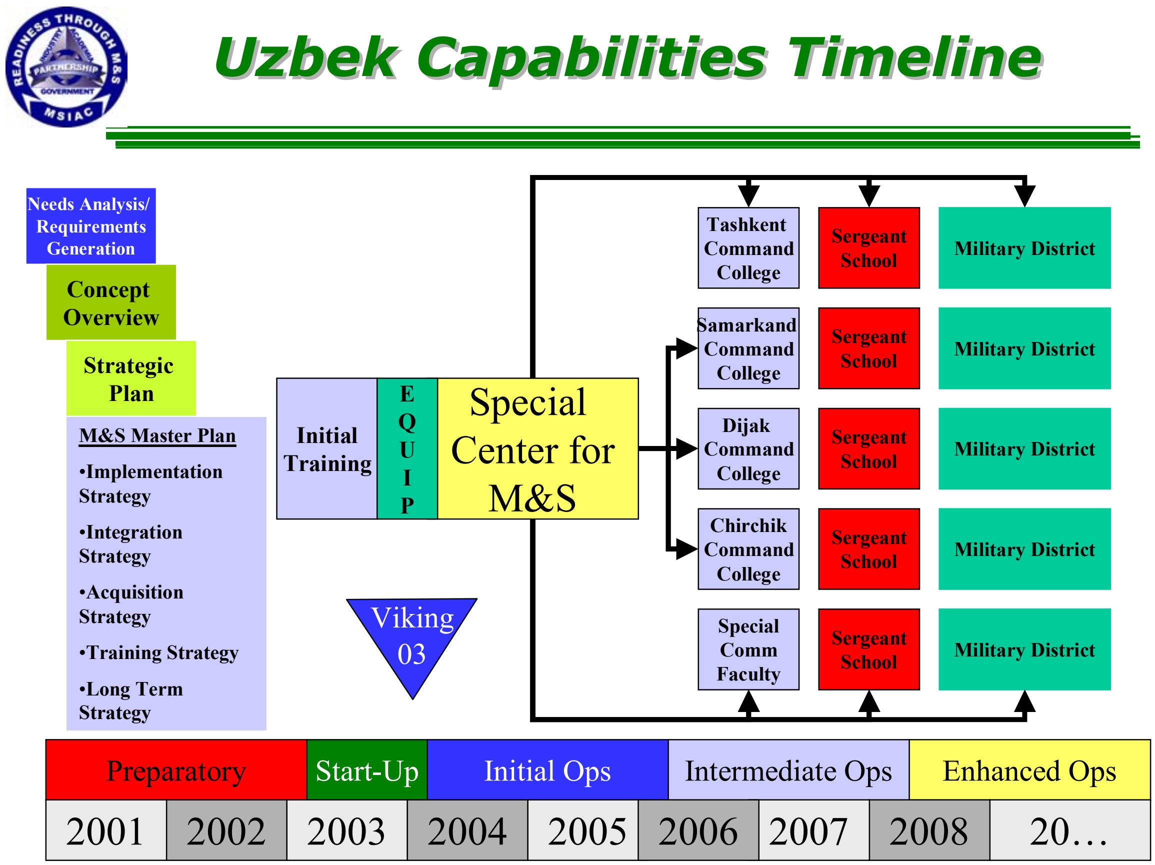
Intermediate Operational

During the Intermediate Phase M&S supported training is expanded to the Military Colleges and Sergeants Schools. During this phase, M&S will be used for training in tactical operations. Commanders and staffs will also be provided with M&S capabilities that support operational course of action analysis. Planning and coordination development of capabilities for the next phase is completed. This phase begins in May 2006 and continues through April 2008.

Enhanced Operational

Early in this phase M&S-supported training is expanded in the military districts to support individual soldier training. Additional M&S-based analytical capabilities are provided to further enhance defense planning and analysis, combat and security operations, and military support for civil emergencies. Simulation based acquisition capabilities are provided to support research, technology development, and military equipment and weapon systems acquisition. The enhanced operational phase is an open-ended phase, starting in May 2008.

The diagram below shows the comprehensive M&S/ADL program envisioned to be developed through the partnership between Uzbekistan and the US.



CURRENT STATUS OF UZBEKISTAN M&S/ADL PARTNERSHIP EFFORT

The Uzbek MSWG has had four (4) major meetings each lasting for a week or more. In the time between the meetings, the majority of the work is accomplished. The MSIAC support team in conjunction with the Uzbek members of the MSWG and US Embassy personnel, research, coordinate, develop and prepare draft documents, briefings, plans and projects for the MSWG to discuss and approve during the working group meeting sessions.

The MSWG has developed and approved a Concept Overview document for the project, which describes the current assessment of M&S and ADL capabilities, needs and requirements, and the concept of how to address those identified needs and requirements. This document formed the basis for the discussions during the working group meetings on about how best to focus the efforts of the M&S and ADL initiative. The result of these discussions based on the Concept Overview resulted in another document called the Strategic Plan.

The "Strategic Plan for the Establishment of Modeling and Simulation and Advanced Distributed Learning Capabilities for the Armed Forces of Uzbekistan" or the Uzbek M&S/ADL Strategic Plan was developed to provide the strategic direction or guidance for the initiative. The strategic guidance was merged with resourcing requirements to provide a document that provided sufficient detail to support national programming and budgeting decisions. Specifically, the Uzbek M&S/ADL Strategic Plan was used as the cornerstone document in the development on a National Resolution on the establishment of a Special Center for Modeling and Simulation (SCMS) and a national infrastructure upgrade to support its operations. This document signed by the President of Uzbekistan on July 9, 2002 provided top-level guidance to all Ministries within the Uzbek government on the establishment and support of the new SCMS. Based on this national resolution, the M&S/ADL initiative now has Presidential support and visibility. The rebuilding and upgrade of the building to house the new SCMS is designated to be completed on March 21, 2003 as a result of this national resolution. Additionally, the requested staffing to support the operation of the SCMS was approved in the national resolution.

The centerpiece of the M&S/ADL initiative is the establishment of the SCMS. The facility will be a true national simulation center and will be under the direction and guidance of the Minister of Defense as an operating office under the MOD structure. The simulation center will provide support to the Uzbek Armed Forces and other Ministries involved with Civil Emergency operations. In time, this simulation center will be the central hub in a series of distributed simulation centers across the key organizations of the Uzbek Armed Forces and other Ministries involved with Civil Emergency operations. Currently, eighteen (18) subordinate simulation centers are planned.

The initial training for the operation of the SCMS simulation center will include an initiative in partnership with the US where Uzbek officers travel to the US and work in an US simulation center. The objective of this program, called the Simulation Center Information Exchange Program (SCIEP) is to facilitate the "on-the-job-information transfer" in an actual simulation center environment. Two mid-grade Uzbek officers in key operational positions within the simulation center, with English language capability, will spend six-to-eight weeks in the US participating in the development, conduct and operation of simulation exercises. This program is currently planned for the March-April 2003 timeframe. It will include a mentorship program by the MSIAC focused on the operation of a simulation center and other aspect of the M&S community. Also included in this program are visits to key organizations involved in M&S and ADL activities.

The Uzbek M&S and ADL Master Plan has been completed and the final draft has been rewritten and is in the process of staffing for official approval. The draft Implementation Plan has been written and the draft will be reviewed by the MSWG in November. This Implementation Plan will provide guidance for all of the tasks and actions that will have to be accomplished to establish the SCMS and implement the objectives of the M&S and ADL Master Plan. The Acquisition Strategy is also in draft form and will be reviewed in November by the MSWG; however, a large majority of the near-term decisions contained in the Acquisition Strategy have already been made. The MSWG, based on the earlier identified needs and requirements, began working the Foreign Military Funding (FMF) process. A Letter of Request (LOR) for the initial hardware, software and training to equip the SCMS has been submitted through STRICOM, who has been working as a member of the MSWG. A Letter of Offer and Acceptance (LOA) has been submitted back to Uzbekistan by STRICOM and is in the process of being signed by the Uzbek Minister of Defense. This will start the procurement of the equipment and software for the installation that is scheduled to begin on May 4, 2003. Once the installation is complete, a train-up period of about three weeks will be conducted to train the Uzbek operators in the SCMS on how to operate the simulation Janus. Janus was chosen as the simulation to use to begin operations in the SCMS, based on Uzbek operational and training requirements and an assessment of current capabilities, Two more critical components of the SCMS are the Simulation Resource Library (SRL) and ADL Digital Library (DL). These libraries will enable the SCMS to function as the central M&S and ADL repository for information and data for the Uzbek Armed Forces. The development effort for these libraries is ongoing and will provide a capability that is compatible with NATO/PfP efforts.

Key future events for the SCMS include a visit by the President of Uzbekistan possibly in the September 2003 timeframe. This visit will include the official dedication of the SCMS and observing a actual simulation exercise. In December 2003, the SCMS will participate in the PfP exercise, Viking 03. Viking 03 exercise will be hosted by Sweden with potentially 27 countries participating in that exercise. Uzbekistan will participate as a remote site with the SCMS operating as a battalion level response cell and will be equipped to be self-sufficient due to the fielding of SCMS and the coordination efforts of the US Enterprise Team. In addition to these events, the SCMS has the mission to support Uzbek Military Academy training and educational requirements with the use of M&S and ADL. Efforts to integrate M&S and ADL into the curriculum of the Academy will be ongoing and the development of unique courses and scenarios for the Uzbek Armed Forces will be accomplished as well.

SUMMARY

The goal and approach undertaken by the MSIAC in support of the MSWG is to train and educate the Uzbek Armed Forces to be able to conduct M&S and ADL activities using their own equipment and people. The successful establishment of the SCMS will be critical to the future success of the long-term program. The National Resolution signed by the President of Uzbekistan has been a major step toward that success.

In addition to the signing of the National Resolution, several important trends have been identified that have truly made this initiative successful. The first is the solid and unwavering support of this initiative from the Uzbekistan MOD and US OSD (ISP) leadership. This solid partnership has enabled the MSWG to produce results quickly. The continuity of Uzbek and US members in the MSWG has assisted in the development of a solid and confident partnership that is working toward a common goal. The use of the strategic planning efforts part of the educational process has also contributed to the near and long term success of this initiative by enabling all members of the MSWG to develop an understanding of all parts of the Master Plan. The assignment by the Uzbek Minister of Defense of outstanding and capable officers to be members of the MSWG and his leadership in this effort has proven to be a major part of its success. And finally, the involvement of the MSIAC as the central coordinator of this initiative along with its partnership with the US Enterprise Team has allowed this initiative to move forward in a coordinated and highly efficient manner. All these factors have already contributed to the perception that this is a highly successful effort. It is through this partnership that the Uzbek MOD will be able to establish the Special Center for Modeling and Simulation (SCMS) as the centerpiece of a national M&S infrastructure and achieve a coordinated and integrated M&S infrastructure that will fundamentally improve the future capability of the Uzbek Armed Forces.

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South Eastern Europe Cooperation in the Field of Modeling and Simulation

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ABSTRACT

In this paper we present an overview of our regional cooperation in the field of modeling and simulation. The use of modelling and simulation is a flexible and a cost-effective tool for improvement of military education, training, exercising and defense planning. It also promotes interoperability with NATO. We are a member of the South Eastern Defense Ministerial (SEDM initiative – Albania, Bulgaria, Croatia, Greece, Italy, Macedonia, Romania, Slovenia, Turkey) and we participate in all regional conferences and exercises in the field of civil-military emergency planning, like CMEP Workshops and SEESIM exercise. Most of these events are concerned with mutual cooperation and giving assistance in case of natural disasters (earthquakes, floods, fires etc.). They are Computer Aided Exercises (CAX), which use Internet and GIS technology as their bases. Our Military Academy has intensive bilateral cooperation with all regional countries. On these bases we have organized the First Symposium for Military Technology, which was held in Ohrid, Republic of Macedonia, on 25-28 September 2002. Some of the topics during the Symposium were closely connected with the field of modeling and simulations.

Keywords: *Modeling and Simulation, Cooperation in South-Eastern Europe, Computer Aided Exercise.*

SECURITY CONTEXT IN SOUTH EASTERN EUROPE

Countries in the South Eastern Europe (SEE) have to face a wide range of difficulties that are always associated with transitional periods. For these reasons the South Eastern European nations were aware that they must be prepared to commit themselves to far-reaching political, security, economic and social reconstruction.

The logic of the stabilization of the South East Europe requires a complex approach for achieving lasting peace, stability and security in the region. There is no doubt that the way out of the entire situation is exclusively through political, economic and security cooperation. The promotion of transparency and mutual confidence in defence and security related issues are between the key tracks that lay at the basis of the regional military cooperation and partnership for peace.

Against this background, the Defense Ministers of nine South Eastern European countries and the US initiated the Southeast European Defense Ministerial (SEDM) process which aims to contribute to regional security and stability and enhance regional cooperation. The SEDM process brings together, under the same umbrella, NATO countries as well as Partnership for Peace nations. This initiative provides a valuable political and military framework, enhances regional cooperation, shapes mentality and promotes cooperation between countries that have common security goals.

[1] Turkey recognises the Republic of Macedonia with its constitutional name.

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

SEDM gives a new dimension to defense diplomacy enforced by its military component that is the South East European Brigade (SEEBRIG), the first success story, as we like to call it, a truly multinational regional force in South Eastern Europe.

The multitude of South Eastern Europe initiatives proves that this part of the world is determined to work according to the principle of regional ownership, to closely cooperate with Euro-Atlantic structures and to further develop regional security capabilities. A closer co-operation between SEDM and NATO's South Eastern Europe Initiative is needed.

Among the main objectives there are capitalizing bilaterally and multilaterally gained experience in different fields, such as improvement of military education and training, increasing public awareness regarding fight against terrorism and exploring new cooperation opportunities with other international organizations (NATO, EU, OSCE etc.).

Countries from the South Eastern Europe region that cooperate in the Euro-Atlantic format make significant and systematic efforts to accomplish real progress in interoperability, implementation of an effective democratic oversight of military activities and full modernization of the existing system of military education and training. There is shared understanding that success in the coming years will depend to a great extent on the reform in the way of teaching and training military professionals.

Education and training are the shortest way to new military professionalism, interoperability and integration. The transparent cooperation in defence education and research can contribute to mutual confidence across the region.

Long-range vision of NATO Partnership for Peace is to create distributed environment in which all nations, including their universities and academies, have an equal opportunity to use, develop, deliver, and manage different kind of training and learning tools. Among these is modeling and simulation as a tool for improvement of military education and training. All these efforts are designed to harmonize and greatly enhance military and defence related education and training at all levels.

Common training would help nations to capitalise accumulated experience in addressing new security risks. At the same time, it could be an incentive to identify common approach and common course of action in coping with new security challenges. Moreover, it could result in improving or alleviating identified shortfalls in military and non-military capabilities that are required in the fight against terrorism. Making use of NATO/PfP appropriate models could be envisaged, in full compliance with the main objectives of the concept document.

In the next few years we expect revolutionary changes in security and defence related studies and military education and training. Distance learning, together with modelling and simulations, will change the way armed forces are trained. Increasing global competition, rapid technological advances, demographic changes, and the emergence of a service and knowledge-based economy impel military organisations to train and re-train their force in a new paradigm. Only these academies and training centers that deploy and effectively utilize modeling and simulations and Advanced Distributed Learning (ADL) will have a distinct competitive advantage.

IMPLEMENTATION OF MODELING AND SIMULATION IN THE MILITARY EDUCATION AND TRAINING PROMOTE INTEROPERABILITY WITH NATO

The use of modelling and simulation is a flexible and a cost-effective tool for improvement of the military education, training, exercising and defense planning. Simulations could cover various aspects of military operations and they are valuable tools for staff training and After Action Review (AAR). The new generation of multisided, interactive simulations allow fast, cost-effective planning, evaluation, and training for almost any situation that involves multiple persons or agencies working together for a common goal. Simulations can assist with resource allocation and scheduling, coordination in and between units, management decision making, procurement planning, and tactics.

The simulation of combat, or a wargame, is used more and more extensively to reduce cost and maintain a trained force. It is an inexpensive alternative to live training exercises. Simulations are also very useful for testing and evaluating proposed procedure strategies and various systems such as economics, weapons, communications and civil architecture.

As the military moves into non-traditional missions such as large scale evacuations, peacekeeping, and famine relief, simulations help to train military leaders without large investment. These simulation programs are not intended to train individual solders or other participants in conflict; rather, they train mission leaders. By participating in different scenarios, leaders learn how to respond to a wide variety of situations. For military training, simulations are particularly useful now because military organizations can afford fewer training hours and smaller expenditures during field exercises. This is especially problem for smaller countries with restricted budgets, and this mean that they mast regionally cooperate in this field.

Because of severe constraints in time, money, personnel and access to units and terrain, a need for simulations defined as “replication of reality as much as possible with models used in a game-engine (computer)” is imminent in order to enhance the ability to conduct operations. This is for most, if not all states, true, both on national and international basis.

Interoperability towards NATO standards for conducting Combined Military Operations and Operations Other Than War (like Peace Support Operations), require basic education, training and exercising based on common procedures and standards. Using modelling and simulation for conducting Computer Aided Exercises in which those standards and procedures are incorporated can significantly improve training of the multinational staff ant its ability to conduct joint and combined operations.

Modelling and simulation can provide readily available, flexible and cost-effective means to enhance NATO operations dramatically in the application areas of defense planning, training, exercises, support operations, research, technology development and armament acquisition. This vision assigns a very important role to modeling and simulation and must be supported from all countries that want to be interoperable with NATO. Computer Aided Exercises will further become more and more common in all multinational training activities organized by NATO. This means that implementing modelling and simulations in military education and training will help every NATO aspirant country to make the necessary progress in the preparation for NATO integration.

Taking into consideration that the base for a successful cooperation among partner nations is interoperability, establishment of PfP the Training and Education Enhancement Program (TEEP) provides advice on interoperability and identifies the requirements for Advanced Distributed Learning and simulation. Military advice on essential areas of interoperability for Partners has been introduced and reflected in PfP Planning and Review Process (PARP) ministerial guidance. These essential areas include:

- The ability to communicate effectively (to include language, procedures, and terminology);
- Command and control arrangements;
- Understanding of Alliance’s military doctrine, standards, and procedures.

Clearly, Partner interoperability with NATO can be facilitated through language training and training of NATO concepts, doctrines, and procedures. But, using modelling and simulation to conduct Computer Aided Exercises in which the operational language is one of the NATO official languages – English, and in which those standards and procedures are incorporated can significantly improve interoperability.

With the combination of ADL and the implementation of modelling ant simulations through conducting Computer Aided Exercises the following can be advanced:

- General knowledge of NATO operational language;
- Basic knowledge of the generic NATO working environment, for example, the internal structure of the Land Forces headquarters from G1 to G6; map symbology; or legal arrangements for participation in collective defense systems;
- Specialized language terminology, for example, basic words, acronyms, and mission specific expressions such as those used for mine clearing or close air support;
- Knowledge and practice of NATO staff procedures, for example, exercise planning, air defense procedures, medical C 2 procedures, etc.

The role of Advanced Distributed Learning in the process of better implementation of modeling and simulations in education and training can be seen in the following:

- Learning different contents (different kind of Education courses) through courses that are available at home, and that mean cost effectiveness;
- Providing Training courses at the individual, collective, operational and strategic levels, the sort of teaching material that are needed to digest before exercising with Computer Aided Exercises or practicing an exercise with distributed simulations;
- Learning about the organization, structure and scenario of the Computer Aided Exercises.

To have better interoperability with NATO Partner nations will need support to establish and improve infrastructures and capabilities for Modeling and Simulations (M&S) and Advanced Distributed learning (ADL) in order to provide education and national training, and also capability to take part in NATO/PfP training/exercises. In this context, regional cooperation in the field of modeling and simulations is very important.

SEESIM EXERCISE

The SEESIM Experts' Group was established to implement the SEESIM initiative approved by ten Defense Ministers (of Albania, Bulgaria, Croatia, Greece, Italy, Macedonia, Romania, Slovenia, Turkey, and the United States) during the October 2000 meeting of the South Eastern Europe Defense Ministerial (SEDM) process.

SEESIM was designed as a tool to integrate – through a series of simulation-based exercises – various initiatives and information networks in the region sponsored, supported, or endorsed by SEDM. These include, for example, the Multinational Peace Force, South Eastern Europe (MPFSEE or the SEE Brigade – SEEBRIG), the Engineer Task Force (ETF), PIMS, and the emerging Civil-Military Emergency Planning Council for South Eastern Europe.

The first SEESIM event will be a demonstration and exercise hosted by Greece in 2002. These will be based on a civil disaster scenario caused by severe, simultaneous earthquakes in several countries of the region. Civil protection bodies will therefore play a major role in simulations designed, among other things, to strengthen military support for civil authorities during civil emergencies.

The SEESIM Experts' Group held its first meeting in Athens, Greece, 12-13 December 2000 and developed Terms of Reference (TOR) for its work. It is co-chaired by Greece and the United States. The TOR established three bodies within the SEESIM Experts' Group: Steering, Technical, and Operational group.

Each SEDM nation has one military representative on the SEESIM Steering Group, which provides policy guidance to the subordinate Technical and Operational Working Groups. The Technical Working Group defines the technical requirements, network standards and architecture, and communications resources necessary to support the demonstration and exercise in 2002. The Operational Working Group develops the scenario and training objectives, defines the training audience, and addresses the coordination necessary to successfully conduct the demonstration and exercise.

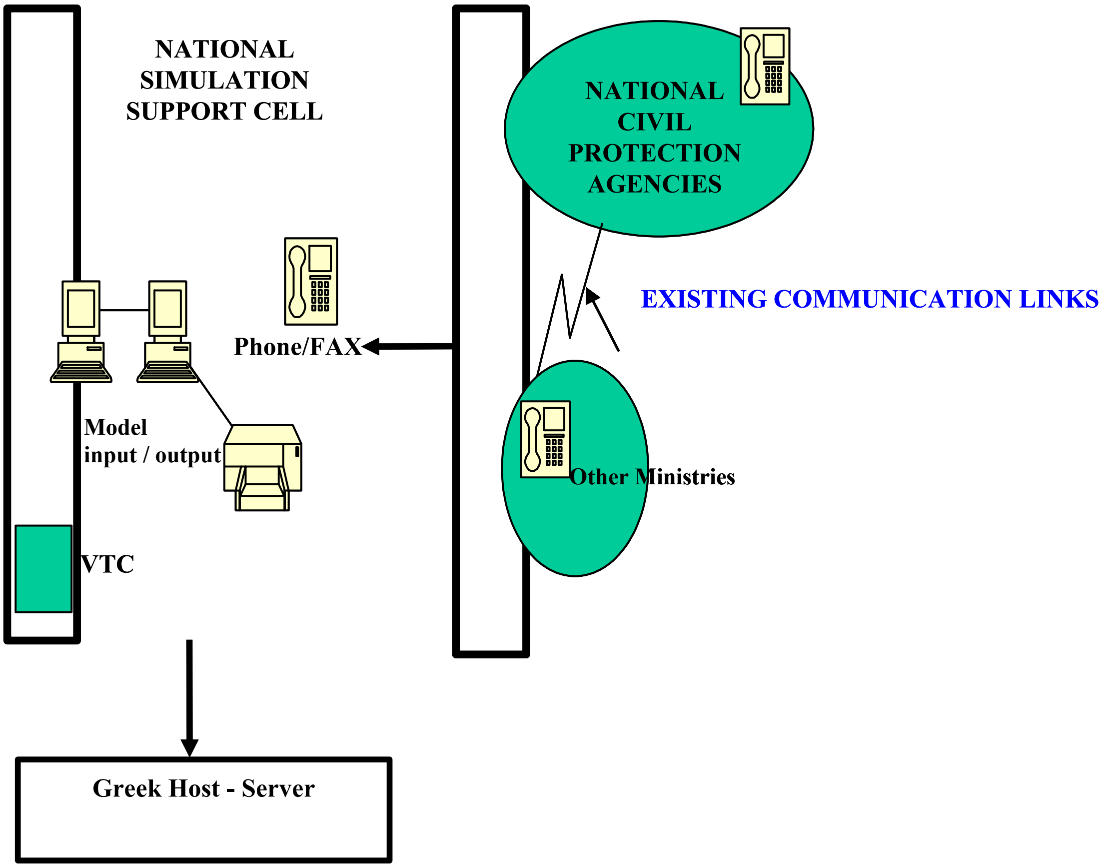
Since the scenario for 2002 is based on a civil emergency, one civil protection and one military representative from each SEDM nation sit on the SEESIM Technical Working Group, and one civil protection and one military representative on the SEESIM Operational Working Group. In addition, the current head of the Civil-Military Emergency Planning Council for South Eastern Europe was designated co-chair – together with the SEEBRIG Commander or his representative – of the SEESIM Operational Working Group.

Training objectives for SEDM countries are:

- Exercise national civil-military emergency procedures.
- Exercise the staffs of Military and Civil Protection Agencies and other responding organizations.
- Exercise each SEDM nation's ability to plan and provide assistance to other nations in the region.
- Exercise emergency information exchange among nations with organizations such as EADRCC.
- Exercise existing communications available to the participating nations.
- Exercise the SEEBRIG Headquarters during regional emergency planning and response to natural disasters.
- Exercise existing commercial phones, fax, email, and the Partnership for Peace Information Management System (PIMS) available to national civil-military emergency organizations in South Eastern Europe.

Proposed SEESIM Scenario Concept:

- Major earthquake damage in affected nations.
- There are two groups of affected nations. (Grouping determined by Operational WG-based on geological facts and bilateral CMEP agreements).
  - 3-day sessions for each affected nation group.
  - Other nations provide support as requested.
  - Affected nation and support nation roles rotate at end of session #1.
- Major roles for National Military and Civil Agencies, Euro Atlantic Disaster Response Coordination Center (EADRCC), NATO, UN, SEEBRIG/ETF, and Non-Governmental Organizations (NGOs).



Creating Events:

- Using scenarios to represent key activities, which support training objectives.
- Master Scenario Events List (MSEL).
  - An activity or event that causes a decision or action by the training audience that allows the training objectives to be met.
  - Are pre-planned activities or events manually inserted or generated by JTLS.

Potential military tasks:

- Provide a Secure Environment
  - For the affected population and relief agencies

- Transport
  - Arrange movement of life-saving goods and personnel via military aircraft, etc.
- Logistic Coordination
  - Warehousing, cargo handling, repairs, etc.
- Communications
  - Assist in unclassified communications
- Information Sharing
  - Security situation, planned movement, etc.
- Relief Distribution
- Exercise Support Manning
- SEEBRIG/ETF
  - Operations Coordination Center?
  - Cross-border movement coordination?
  - International logistics coordination?

Exercise components:

- Simulation Host Nation (Greece in 2002)
  - Runs Joint Theater Level Simulation (JTLS) and is linked to National Simulation Support Cells (NSSC) in all participating Nations.
  - Provides exercise feedback and ensures successful completion of demonstration and exercise through the multinational control group in Athens.
- National Simulation Support Cells (NSSC)
  - Two-way information link between the JTLS model in Athens and the National Civil Protection and Military Agencies.
- National Military and Civil Protection Agencies
  - Primary Training Audience.
  - Receive JTLS model information via National Simulation Support Cell (NSSC).
  - Use current real-world capabilities to deal with disaster response (Telephones, FAX, Email, Maps).

Training audience:

- Primary Training Audience:
  - National Military and Civil Protection Agencies
  - Other responding organizations in each nation (Red Cross etc.)
  - The South Eastern Europe Brigade (SEEBRIG) Headquarters
- Other Participants:
  - Euro-Atlantic Disaster Response Coordination Center (EADRCC)
  - NATO Civil Emergency Planning Directorate (CEPD)
  - UN Office for the Coordination of Humanitarian Affairs (OCHA)
  - Non-Governmental Organizations (NGOs)

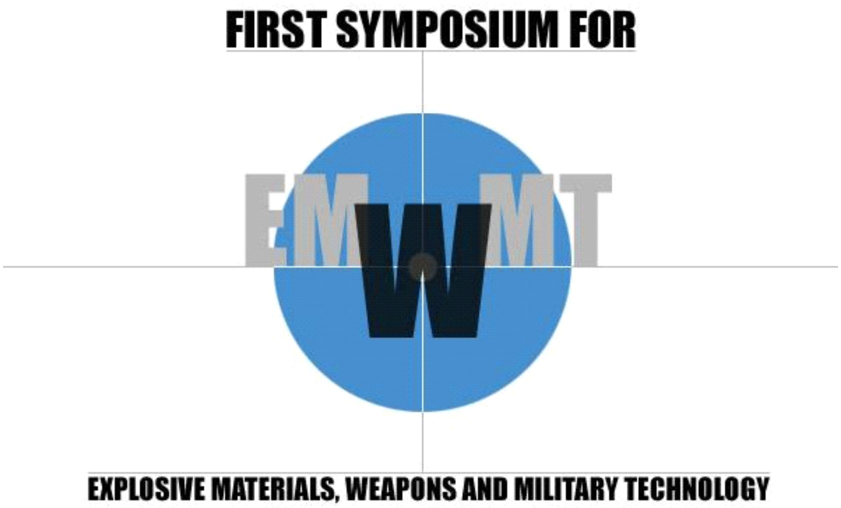
Entities (resources) in the Simulation – JTLS Database:

- Response units: personnel and equipment organized to provide capability in a disaster, for example:
  - Medical teams and hospitals
  - Search and Rescue teams
  - Helicopter units for transport, reconnaissance, evacuation
- Response Material: supplies and other items provided to assist victims of disasters, for example:
  - Tents
  - Blankets
  - Food
  - Water
  - Medical supplies

THE FIRST SYMPOSIUM FOR EXPLOSIVE MATERIALS, WEAPONS AND MILITARY TECHNOLOGY

The First Symposium for Explosive Materials, Weapons and Military Technology was held in Ohrid – a famous tourist, historical and cultural center by the beautiful Ohrid lake, in the Republic of Macedonia, on 25-28 September 2002. The Symposium was organized by the Military Academy "General Mihailo Apostolski", and sponsored by the Ministry of Defense of Republic of Macedonia, in cooperation with the applicative production companies.

The Symposium was thematically focused on determined military – technological areas, military techniques and technology. The following topics were included: explosive materials, ballistics, ammunition, classic armament, rocket systems, systems for fire control, training simulators, composite materials, resources for ballistics defence, and standardization and the quality of the armament and military equipment.



25-28 September 2002, Ohrid – Republic of Macedonia

The main objective of the Symposium was to provide professional change of scientific-professional knowledge, information and experiences between the people and institutions in the region and in the

World, who deal with educative, scientific-research work, applicative and productive work, connected to the above mentioned areas.

The symposium had a special dimension in emphasizing the cooperation between the countries in the region and wider, through realization of mutual scientific – research projects. This kind of cooperation contributes in reaching the criteria and standards, important for NATO's membership.

For the Symposium, a lot of authors' works were applied from different countries in the region and in the world, such as: Bosnia and Herzegovina, Republic of Bulgaria, The German Federal Republic, Federal Republic of Yugoslavia, USA, Republic of Croatia and Republic of Macedonia. Representatives from Republic of Slovenia and Republic of Turkey also took part in the Symposium.

Some of the topics in the Symposium were closely connected with the field of modeling and simulation, and those are given as follows:

- *Missile systems* (unguided and guided missiles; rocket motors; light unguided anti-tank weapons; anti-tank guided weapons; surface-to-air and air-to-surface guided weapons; guidance and control systems; combat use of missile systems).
- *Fire control systems* (fire control systems for artillery and missile systems; sensors; detection, identification and acquisition of targets; ballistic computers and algorithms; automation of shooting process).
- *Simulators and training equipment* (modelling and simulations of projectiles and missiles; simulation and testing of guidance and control systems; hardware-in-the-loop simulations; simulators for research and training simulators).
- *Ballistics* (internal and external ballistics; terminal, wound and experimental ballistics; ballistics instrumentation, measurement methods and measurement in ballistics).

A lot of works presented in the Symposium were focused on the subjects like: simulation of automated data exchange in tactical units, modeling and optimization of fire-system combat effectiveness, computer simulations for the analysis of projectiles trajectory, simulation and analysis of fuzzy homing guidance systems of missiles, fuzzy-logic control of mobile robots, etc.

During the Symposium we exchanged our previous investigations and results with our colleagues, which are also Partnership for Peace members. Also, we considered that regional cooperation in this field is very important.

CONCLUSION

The logic of the stabilization of the South East Europe requires a complex approach for achieving lasting peace, stability and security in the region. Promotion of transparency and mutual confidence in defence and security related issues are between the key tracks that lay at the basis of the regional military cooperation and partnership for peace.

Regional cooperation and common training using modeling and simulations would help nations to capitalise accumulated experience in addressing new security risks. Distance learning, together with modelling and simulations, will change the way armed forces are trained.

Good example of the regional cooperation in SEE is the SEESIM exercise designed as a tool to integrate – through a series of simulation-based exercises – various initiatives and information networks in the region sponsored, supported, or endorsed by SEDM.

The First Symposium for Explosive Materials, Weapons and Military Technology had a special dimension in indicating the cooperation between the countries in the region and wider, through realization of together scientific – research projects. A lot of the works presented in the Symposium were closely connected with the field of modeling and simulation. This kind of cooperation contributes in reaching the criteria and standards, important for NATO's membership.

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The Enterprise Team: The United States Modeling and Simulation Collaboration Assistance Effort

A U.S. Program to Improve Interoperability in Support of Global Networking, Modeling & Simulation, and Peace Support Initiatives

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In the year 2000 representatives from the U.S. Joint Forces Command (USJFCOM), U.S. NAVAIR Orlando Training Systems Division (TSD), and U.S. Army Simulation, Training, and Instrumentation Command (STRICOM), working on different programs but supporting the same Partnership for Peace (PfP) nations, discovered that they had overlapping goals and were using common resources. Representatives from these organizations decided they could better serve U.S. interests, save resources and provide more capable, integrated and interoperable systems if they coordinated their efforts. Another impetus to working cooperatively was the establishment of USJFCOM as the lead agent for the Regional Security Cooperation Network [1] (RSCN). The RSCN was designed to facilitate coalition-based distributed education and training, building on existing information technology efforts. As a result, representatives from these three organizations decided to form the "Enterprise Team" to better cooperate while implementing their individual programs.

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

This informal team meets periodically to brief the members on their individual programs and look for ways to support each other's security assistance programs. The Enterprise Team's primary product is integrated, interoperable systems that support national security objectives and facilitate international cooperation. The U.S. Air Force Electronic Systems Center and U.S. Modeling and Simulation Information Analysis Center (MSIAC) joined the team in 2001 and 2002, respectively. Of note, each organization maintains control of its programs while supporting the overall team objectives, whenever the benefits of doing so are clear.

The benefits of Enterprise Team activity are clear: each organization brings unique capabilities and different perspectives, resulting in a "Big Picture" approach to meeting national and regional security objectives. As representatives of their parent military organizations, Enterprise Team members operate with professionalism, commitment, and mutual respect to provide the best capability to support PfP nation objectives.

KEY CONCEPT

The Enterprise Team will use a teaming concept and leverage all resources, funding, and programs wherever possible to achieve individual and collective goals and objectives in the spirit of mutual cooperation in the global security environment.

TEAM MEMBERS

The following sections outline the key security assistance programs supported by the Enterprise Team organizations:

U.S. Joint Forces Command (USJFCOM)

Headquartered in Norfolk, Va., U.S. Joint Forces Command is one of ten unified commands in the Department of Defense. USJFCOM's functional responsibilities reflect a role in transforming US military forces to meet the security challenges of the 21st century. As the lead Joint Force Integrator, USJFCOM is responsible for combining Service and Defense agency capabilities to enhance interoperability and joint and combined capabilities by recommending changes in doctrine, organization, training, material, leadership and education, personnel, and facilities. As the lead agent for Joint Force Training, USJFCOM is responsible for managing the combatant commander's portion of the CJCS exercise program, conducting and assessing joint and multinational training and exercises, and leading the development and operation of systems and architectures that directly support the distributed joint training requirements.

The Defense Planning Guidance (UDP) 04-09 [2] states that unified commands will continue to strengthen alliances and partnerships. As emphasis, UDP 04-09 also states, "the [U.S.] Defense Strategy is premised on strengthening America's alliances and partnerships and developing new forms of security cooperation.

Deputy Secretary of Defense [3] identified USJFCOM as the lead for the advanced distributed learning Regional Security Cooperation Network (RSCN), which leads the development and operation of systems and architectures that directly support the distributed joint training requirements of other regional combatant commanders, joint task forces and defense agencies.

One of the Enterprise Team's key cooperative activities is the support of USJFCOM in its PfP leadership role, especially in organizing PfP computer-assisted exercises (CAXs). USJFCOM provides systems engineering, technical assistance, funding, and equipment to support numerous PfP CAXs conducted on a regional scale. Other Enterprise Team members often support communications, modeling and simulation, and training initiatives in nations participating in these regional exercises. This presents opportunities for sharing resources, planning programs that are mutually supportive, and integrating systems that have cross-program and regional compatibility. Mr. Dan Collins, Senior Systems Analyst notes that, "the ET makes small adjustments to resources to yield increased capabilities for nations."

USJFCOM provides support through the NATO PfP Training and Education Enhancement Program (TEEP). The TEEP's objective is:

> …to provide a structured approach to optimize and improve training and education in the Partnership. Its principal aim is to increase the ability of training and education efforts to meet current and future demands of an enhanced and more operational Partnership, focusing specifically on the achievement of interoperability. It also seeks to promote greater cooperation and dialogue among the wider defence and security communities in NATO and Partner nations. [4]

USJFCOM recently supported or currently supports the following PfP and "In the Spirit of" PfP initiatives and computer-assisted exercises: PfP Simulation Network (PfP SIMNET), Baltic Simulation Network (BALTSIM), Viking 01, Rescuer/MEDCUR 02, Southeastern Europe Simulation Network (SEESIM), SEESIM 02, Cooperative Telos 03, Cooperative Osprey 03, and Viking 03. The goals of these exercises are to enhance regional security cooperation, provide staff officer training and provide experience in using CAXs to support training.

BALTSIM is a regional application of the USJFCOM -developed PfP SIMNET within the Baltic nations of Estonia, Latvia and Lithuania. The Baltic Defense College serves as a distribution hub with response cells in each of the three nations. The PfP SIMNET supports the distribution of the exercise throughout the region, allows the joining of other distributed international CAXs, and can be used for distance learning when not being used for a CAX.

The Viking exercise series is a biennial Swedish-led peace support operation (PSO) CAX. USJFCOM provides the primary technical support through a U.S. and Sweden memorandum of understanding. Seventeen nations and 450 personnel participated in Viking 01.

Rescuer/MEDCEUR 02 was a U.S. Navy Europe (USNAVEUR) –led exercise sponsored by the Chairman of the U.S. Joint Chief of Staff. The scenario was humanitarian assistance and disaster relief (HA/DR). Key activities included a disaster relief effort in Lithuania, a search and rescue effort in Latvia, and a medical capability element in Estonia. Other participants were Finland, Germany, The Netherlands, Norway, Sweden, Poland, United Kingdom and the United States. The exercise used existing national training facilities with additional communications links added, as needed. Command and control was conducted through video teleconferencing and Voice Over Internet Protocol (VoIP) telephones. USJFCOM functioned as the technical systems integrator.

In October 2000, the ministers of the South Eastern Europe Defence Ministerial (SEDM) agreed to move forward on a Southeastern European Simulation Network (SEESIM) as a tool for integrating several related SEDM initiatives through a series of simulation-based exercises, with the first exercise planned for 2002. The ministers' mandate to establish SEESIM fulfills both SEDM regional initiatives and NATO's Southeastern Europe Initiative. For the first SEESIM exercise, SEESIM 02, USJFCOM provides a co-chair for the Technical Working Group, and this representative is an Enterprise Team member.

The first exercise, SEESIM 02, will involve three (3) earthquake scenarios, where the natural disaster affects more than one country and requires a coordinated regional response effort. The training objectives include the response of National Civil Protection agencies within each nation and their use of assets from other nations, to include personnel and other resources organized under the Ministry of Defense. To assist in planning the participation of Civil Protection organization, the U.S. Office of the Secretary of Defense (International Security Affairs/Southeastern Europe) has tasked leaders of the Civil-military Emergency Planning team (CMEP). The exercise will stress regional cooperation and the sharing of other-nation assets in disaster relief efforts. The magnitude of the simulated earthquakes provides a realistic framework where integration of the South-Eastern Europe Brigade (SEEBRIG) and the resolution of regional interoperability and communications issues are essential to a successful relief effort. For the SEESIM 02 exercise, Greece is serving as the network hub with simulation centers in Albania, Bulgaria, Croatia, Macedonia, Romania, Slovenia, Turkey and SEEBRIG (headquartered in Plovdiv, Bulgaria). USJFCOM functions as the technical systems integrator. STRICOM, another Enterprise Team member, has established a constructive simulation capability in six of the participating nations, and these national training facilities are being leveraged for the SEESIM 02 exercise.

U.S. Navair Orlando Training Systems Division (TSD)

TSD is headquartered in Orlando, Florida. The mission of TSD is to be the principal Navy center for research, development, test and evaluation, acquisition and product support of training systems, to provide interservice coordination and training systems support for the Army and Air Force, and to perform such other functions and tasks as directed by higher authority Its vision is to be the Navy and Marine Corps center for learning and simulation technologies, methods, processes and systems to further develop the National Center of Excellence for Simulation and Training in partnership with Army, Air Force, DoD, other Government Agencies, Industry and Academia.

The TSD Program Director for International Programs (PDI) manages the Defense Security Assistance Program; distributing policy guidance and standardized procedures; executing Foreign Military Sales (FMS) cases and monitoring programs for training systems and equipment sold to allies; coordinating foreign disclosure, export licensing and foreign visit requests; and assisting the Navy International Program office and the Naval Air Systems Command Headquarters. One of the responsibilities of PDI is to execute the Enhanced International Peacekeeping Capabilities (EIPC) program.

EIPC is a State Department program supporting peacekeeping training in other than NATO nations. Currently, the program supports 27 nations. Its goal is to increase the effectiveness of international peacekeeping operations through the provision of equipment and training. The recipient nations use the equipment and training to increase the pool of qualified peacekeeping forces using a “train the trainer” concept. Training equipment is tailored to the type of force the recipient nation is expected to field, the level of existing technical expertise in the country, and the country’s ability to maintain and operate the equipment during its service life (EIPC provides start up costs, but not maintenance). For the most technologically capable countries, EIPC training equipment can include establishing Local Area Networks and electronic classrooms, mobile communications equipment, staff training software and models, exercise media and connectivity, driving simulators and optical equipment. EIPC provides funds for attending training seminars and conferences, procuring manuals, books and library materials and provisioning English language laboratories.

EIPC can provide, using a common operating architecture, electronic training environments (ETE) that are connected to local area networks. The ETEs are advanced classrooms, equipped with computer-supported instructor and student workstations, Electronic Classroom Integration Software (ECIS), projection systems, “Smart” boards, and other advance audio and video systems. The systems are designed to be integrated with advanced distributed learning applications, computer-assisted exercise training, English language training and other training devices.

EIPC was recently implemented in several countries: Poland, Nepal, Czech Republic, Hungary, and Ukraine. In the Ukraine, the goal was to enhance the training capabilities and conduct multinational staff training at the National Defense Academy. TSD integrated a local area network with computer-equipped classrooms, provided instructor preparation and course development centers, Learning resource centers, multipurpose electronic classroom, a conferencing facility, and connectivity to the PfP Information Management Systems (PIMS) network. Due to prior collaboration with other Enterprise Team members, the majority of the equipment installed under the EIPC program can be integrated with future information technology and modeling and simulation initiatives.

U.S. Army Simulation, Training, and Instrumentation Command (STRICOM)

STRICOM is based in Orlando, Florida. This command is responsible for the development and sustainment of training and test simulation, simulators, targets and instrumentation devices for the U. S. Army. STRICOM's mission includes the creation of a synthetic environment to evaluate and support requirements definition, materiel development, and test and evaluation; leveraging live, virtual and constructive to develop a system of systems that train the way we fight; and provide materiel life cycle support from concept development through disposal.

STRICOM manages the majority of the U.S. Army's fielded training aids, devices, simulators and simulations. They provide worldwide support for 394 different types of live, virtual and constructive training systems. Over 2100 people are committed in direct support.

STRICOM recognizes that its mission goes beyond the development of live, virtual and constructive simulation, and in a broader sense is to integrate these technologies both from a technical standpoint and an integrated training strategy aspect.. In fact the Command is primarily established along the three domains of simulation, live virtual and constructive. STRICOM attempts to export this same philosophy through its Security Assistance and International Cooperative programs. Many of their international partners are pursuing capabilities in all three domains, with a vision towards integrating these capabilities.

STRICOM's Command Analysis & Planning Office manages the Security Assistance Program and is the single interface with the U.S. Army Security Assistance Command. This includes establishing policy for the Commander, incorporating support to our allies into Command strategic planning, performing on-site surveys to define requirements, providing price and availability data for STRICOM products and services, transitioning acquisition programs throughout the command, and overseeing and closing Security Assistance Foreign Military Sales cases.

STRICOM is enhancing its support to Security Assistance by exporting the corporate vision it maintains for supporting the U.S. Soldier. They envision their organization as on point in the development of interoperable training, testing, instrumentation and simulation solutions for transformation. By relating this strategic vision to the Security Assistance mission they can assist international security partners in determining their needs in the areas of live, virtual and constructive simulation, effecting the transformation of foreign militaries as well.

STRICOM is currently supporting security assistance programs in 49 nations, supporting all five of the U.S. regional combatant commander missions. In carrying out these activities STRICOM has worked with 37 different defense contractors. This wide involvement in security assistance programs means that

STRICOM can use its broad expertise in providing solutions that will support national requirements. They are able to provide the right products and integrate other Enterprise Team member's expertise and products to ensure systems interoperate and provide the best value.

STRICOM provides a wide range of products and services through its security assistance program. Some examples of our live training products are aerial targets, MILES and Instrumentation System support. STRICOM's virtual training products represent the highest dollar value of business. These include gunnery and driver trainers and engagement skills trainers. The area of constructive training products has been the most dynamic in recent years. The number of nations that have obtained or expressed interest in computer-based simulations has increased more than threefold over the past 18-24 months. These products are important tools in transforming military forces to better employ information and other technologies.

U.S. Air Force Electronic Systems Center (ESC)

The Electronic Systems Center (ESC) delivers information dominance for aerospace operations. The ESC portfolio includes delivering capabilities for both combat support in areas such as medicine, logistics, and finance, as well as combat operations for effective command and control (C2) capabilities needed to defend national interests. And ESC is the focal point for the Air Force infrastructure investments to ensure the development and sustainment of interoperable systems that seamlessly work in Joint and international operations. The ESC organizations with the closest ties to the Enterprise Team are the International Operations Office and the Modeling and Simulation Division.

The International Operations Office (ESC/FA) provides a gateway for foreign military sales, armaments cooperation, and technical studies for our international partners, with the studies leading to the most Enterprise Team interaction. ESC has conducted the majority of the studies in Central and Eastern Europe with Partnership for Peace nations. The studies provide technical roadmaps for enhanced interoperability with the US and NATO and cover primarily three areas.

The first is the Regional Aerospace Initiative (RAI). RAI studies provide a blueprint for cooperation between civil and military airspace management not only within specific nations, but also throughout Central and Eastern Europe. One result of the RAI studies is the Air Sovereignty Operations Center (ASOC), which is the hardware suite that implements the RAI plan. Ten nations are currently using ASOCs in the region.

Navigational Aids (NAVAIDS) Studies provide a systematic, incremental set of agreed-upon modifications required by the countries to modernize their military navigational systems and landing aids. NAVAIDS studies evaluate interoperability in the following areas: en route navigation, precision approach, non-precision approach, air-ground communications, avionics, and approach lighting.

The Command and Control, Communications, and Computer (C4) Studies provide action plans for low cost modernizations of a nation's C4 functions. An outgrowth of the C4 Studies is the concept for National Military Command Center (NMCC). The NMCCs are planned as highly capable and affordable national command centers coordinating civilian and military resources for crisis management. The NMCC costs are based on participation by three nations. Currently two nations have committed, a third is in the process of signing the paperwork, and a fourth has voiced strong interest in joining in the system.

The Modeling and Simulation Division (ESC/CXC) is the focal point for ESC's modeling and simulation (M&S) capabilities.

First, ESC manages the development and support of modeling, simulation, and analysis tools. For example, the Air Force M&S Training Toolkit (AFMSTT) is a battlestaff training tool for Joint and combined operations, which provides air warfare simulations and a common operating picture for role-players and controllers. Another tool, the Joint Integrated Mission Model (JIMM), is a mission level analytical simulation used predominantly for the Joint Strike Fighter (JSF) program.

Second, ESC models command and control (C2) architectures and conducts analysis to provide an understanding of the relationships between multiple types and quantities of assets, how they are tasked, communicate, and can be better employed.

Third, CXC manages the C2 Enterprise Integration Facility (CEIF) to support the assessment of C2 systems using tactical systems and simulations as stimulators.

And finally, ESC/CXC is looking to the future with such projects as the creation of a Joint Synthetic Battlespace (JSB), a next generation framework to model consistent environments supporting projects from engineering studies to readiness operations. Successful completion of the JSB vision involves distributed facilities and cooperation spanning government, commercial, and research organizations.

The Electronic Systems Center combines technical and management expertise to provide information solutions for the US and our partners. ESC headquarters is located at Hanscom Air Force Base near Boston, Massachusetts and combines the strengths of its reporting units from across the US and the world.

U.S. Modeling and Simulation Information Analysis Center (MSIAC)

The MSIAC is one of thirteen government-owned, contractor operated information analysis centers under the guidance of the U.S. Defense Technical Information Center. It works closely with the U.S. Defense Modeling and Simulation Office (DMSO). Its mission is to be a center for excellence for modeling and simulation (M&S) knowledge and operational support and to provide M&S solutions and services to defense organizations and industry. The MSIAC staffs are experienced defense and M&S professionals who understand operational problems, training, education and resources. The IIT Research Institute, a not-for-profit organization, operates the MSIAC for the government. The MSIAC main office is located in Alexandria, Virginia.

The MSIAC’s goal is to provide cost-effective M&S solutions in support of military operations, training, combat developments and peace support missions that are designed to optimize a nation’s M&S investment. It can help organizations identify and articulate M&S requirements, assess and integrate current capabilities, providing recommendations, develop affordable executable M&S plans, facilitate personnel and education training, support systems acquisition, and assist in the defining long-term needs for M&S capabilities. As a member of the Enterprise Team the MSIAC is able to play the role of an honest broker, leveraging the entire spectrum of U.S. government M&S capabilities to find the most modern, cost effective, efficient, and integrated solutions to a nation’s M&S requirements.

The MSIAC has extensive international M&S-related experience. The MSIAC, working with DMSO, played a leading role in writing and coordinating NATO’s first M&S Master Plan and establishing the NATO Simulation Coordination Office. They maintain an on-site representative in Korea, assisted in the development of the PfP Simulation Network Five Year Plan, and provided M&S education for the NATO staff and in ten nations. They are currently working with Uzbek Armed Forces to develop a comprehensive M&S capability. Working collaboratively with Uzbek MOD and Armed Forces Academy staffs, USJFCOM and STRICOM, they have completed a requirements analysis, concept document, and strategic plan. A comprehensive M&S master plan is currently being refined.

The MSIAC focuses on requirement determination, strategic planning and education programs. Working in conjunction with the nation and Enterprise Team members, MSIAC facilitates the strategic planning and system integration process. The key to success is working closely with national representatives to refine requirements, carefully consider resources, analyze options and then develop actionable plans.

Based on a nations needs, this planning process could typically include the following products:

- Needs Assessment: Determines requirements, assesses current capabilities, identifies resource constraints and determines prioritized needs.
- Concept Overview Development: Working closely with the customer, develops a strategy, clearly defining the purpose and intent of the M&S capability.
- M&S Master Planning: Develops a detailed time-phased M&S plan that considers resource constraints.
- M&S Education Planning: A coordinated M&S education and training strategy.
- Acquisition Strategy Development: A time-phased acquisition proposal for hardware, software, training and technical support needs. Assist in developing and processing letters of request (LOR).
- Implementation Support Planning: Coordinates in-country assistance to implement phased operational capabilities.
- M&S Enhanced (Future) Operational Planning: Identifies the support required to sustain and enhance current capabilities and meet future requirements.

WORKING AS A TEAM

The Enterprise Team has identified four key objectives to guide team members when executing individual programs in achieving interoperability, meeting a nation's needs and using resources efficiently. The degree at which a team member can support these objectives is dependant upon the specific project requirements, funding limitations, and program maturity. The objectives are:

1) Coordinate individually managed U.S. information technology programs.
2) Promote information technology interoperability through equipment standards and compatibility and advocating the PfP SIMNET as the modeling and simulation standard.
3) Provide advice to nations concerning modeling and simulation (M&S) trends.
4) Help nations meet training needs and achieve greatest return on investment (ROI).

As noted in the team member sections above, the Enterprise Team has collaborated on projects involving numerous nations. They have been successful in leveraging funding streams and coordinating multiple programs. The team has worked together effectively to help clients define and integrate requirements. They promoted interoperability and sharing of resources through the development of a common core equipment list. The team meets periodically to maintain channels of communication.

ACCESSING ENTERPRISE TEAM CAPABILITIES

The international M&S community, and in particular the NATO and PfP countries, can obtain professional, competent and experienced assistance in developing comprehensive and integrated M&S capabilities. Accessing Enterprise Team capabilities can be initiated through any of the team members. Following an initial consultation, additional Enterprise Team members can be added to work collaboratively with the requesting nations. The Enterprise Team can help the nation navigate through the US-provided Foreign Military Financing (FMF), Foreign Military Sales (FMS), EIPC, and International Military Education Training (IMET) programs, and assist in letter of requests (LOR) and letter of acceptance (LOA) processing. They can also assist in requirements definition, strategic planning, education, equipment fielding, training and the conduct of actual Computer Assisted Exercises (CAXs).

ABOUT THE AUTHORS

Mr. John Daniele, U.S. Army Simulation, Training and Instrumentation Command

Mr. Daniele is the Chief Security Assistance and International Programs, and has over 25 years experience in U.S. Army International Affairs having successfully delivered more than a billion dollars of military articles and services to critical allies worldwide. His efforts have played a key role in high priority military aid programs for the governments of El Salvador, Colombia, Haiti and others. Mr. Daniele was instrumental in the first Foreign Military Sale of the U.S. Army's Battery Computer System, exportable SINCGARS radio, Advanced Gunnery Training System and Corps Battle Simulation. Recent successes include a number of high visibility, training modernization efforts in support of NATO expansion, Partnership for Peace, and the Newly Independent States. Mr. Daniele is Chairmen of STRICOM's International Agreements Integrated Process Team which develops, negotiates and establishes cooperative research and development and foreign exchange agreements.

Mr. John Wrigley, U.S. Modeling and Simulation Information Analysis Center

Mr. Wrigley is a Modeling and Simulation Information Analysis Center (MSIAC) project manager for international M&S support. The MSIAC is managed for DoD by IIT Research Institute – he joined the IIT Research Institute, AB Tech Group in 1996 and has supported numerous projects aimed at enhancing the use of M&S in defense organizations. These projects included leading a Weapons of Mass Destruction (WMD) Civil Support Information System (CSIS) requirements analysis, conducting a DoD-wide Warfighter M&S Needs Assessment, coordinating simulation support for a DOT&E-sponsored Interoperability Test Bed initiative, revising the DoD M&S Master Plan, drafting NATO's first M&S Master Plan, and writing the JSIMS Functional Requirements Document. He holds a Modeling and Simulation Professional Certification.

Mr. Harry Thompson, U.S. Modeling and Simulation Information Analysis Center

Mr. Thompson is a Modeling and Simulation Information Analysis Center (MSIAC) project manager for international M&S support. The MSIAC is managed for DoD by IIT Research Institute – he joined the IIT Research Institute, AB Tech Group in 1999 and has supported numerous projects aimed at enhancing the use of M&S in defense organizations. These projects included authoring a DoD M&S Handbook, teaching M&S courses, developing several M&S education lessons and workshops, and assisting with the development of the PfP Simulation network plan. As a U.S Army officer assigned to the Defense Modeling and Simulation Office (DMSO), he led the project to draft the first NATO M&S Master Plan He holds a Modeling and Simulation Professional Certification.

Mr. Dan Collins, U.S. Joint Force Command

Mr. Collins is a Senior Systems Analyst for Joint Warfighting Center, U.S. Joint Forces Command (USJFCOM). He serves as the systems integrator for PfP programs and projects sponsored by Office of the Secretary of Defense (OSD) and USJFCOM. Notable projects include the 50th Anniversary of the NATO Summit, establishment of the Baltic Simulation Network, the Viking series of exercises, the Southeastern Europe Simulation Network (SEESIM) series of CAXs in Balkans. He also serves as the administrator for the Modeling and Simulation Working Group in the PfP Consortium of Defense Academies and Securities Institutes. Additionally, Mr. Collins co-authored the PfP Simulation Network Plan.

As a U.S Army officer he served in various training organizations including the Warrior Preparation Center in Einsiedlerhoff Germany, the Battle Command Training Program (BCTP), and the Center for Army Lessons Learned (CALL) at Ft Leavenworth, Kansas.

Mr. Nabil Morgan, U.S. Navair Orlando Training Systems Division

Mr. Morgan is a NAVAIR Orlando program manager responsible for executing more than 30 Foreign Military Sale cases, from requirement definition through planning, acquisition and delivery. Mr. Morgan holds a degree in Aerospace Engineering, and was a fellow member of the American Institute of Aeronautics and Astronautics (AIAA) from 1983 to 1994. He has also completed graduate studies in Program and Business Management. Mr. Morgan is certified Level III Acquisition Professional in two fields: Program Management; and Systems Planning, Research, Development, and Engineering. During his tenure career with NAVAIR Orlando (TSD), Mr. Morgan holds more than 14 years of U.S. Navy international programs experience that exposed him to the full spectrum of program management and systems acquisition. Mr. Morgan fielded numerous simulators and training systems to various FMS allies. He builds his success on the continuing dialogue with the customer throughout program execution.

Major Scott Lausman, U.S.A.F. Electronic Systems Center

Major Scott A. Lausman is Chief, Business Development Division, International Operations, Electronic Systems Center, Hanscom Air Force Base, Massachusetts. He is responsible for facilitating international activities for an organization of over 10,000 personnel with an annual budget of over $4 billion. Major Lausman received an Air Force Regular Commission in 1986 as a distinguished graduate of the University of Michigan Air Force Reserve Officer Training Corps. He has served as an aerospace engineer for an advanced design shop, an assistant professor at the University of Maryland, a combat simulation analyst of foreign aircraft, and the chief engineer of a satellite communications division. His staff assignments include twice serving as an executive officer and once as the speechwriter for a three-star commander. As the deputy chief, Security Assistance Division, he conducted international communications infrastructure studies and developed operational concepts for US allies. As a chief of support inspections and chief of commander programs, Major Lausman led teams conducting worldwide inspections of Department of Defense intelligence organizations.

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[1] DEPSECDEF Memorandum, 4 August 2000.

[2] Defense Planning Guidance 1904-1909, May 2002.

[3] DeLeon Memo of 4 August 2000, Distributed Learning in Support of Enhanced Regional Security.

[4] Http://www.nato.int/pfp/docu.

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Closing Remarks

Mr. G.J. BURROWS
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I would like to thank all session chairmen for their efforts in keeping the conference on track and running smoothly. Thank you also to the presenters for their efforts both in preparing and giving the various papers, which I consider were an excellent set. Finally, I would like to thank the conference delegates for their participation during questioning, and for their good humour throughout, which I felt contributed to the overall success of the event.

In terms of issues related to Models, the Conference has shown that there was an increasing requirement to address non-physical aspects, such as people, organisations and doctrine. Interoperability between people (as well as equipment), and the representation of military decision processes and asymmetric threats, were examples of this. Another issue relating to modelling was the need to cope with the 'system-of-systems' thinking that is associated with a military-capability approach to acquisition. In particular, this would require models to be composed vertically as well as horizontally, and the provision of tools to support this type of integration.

Regarding Applications, papers during the Conference have highlighted increasing activities in two main areas: C4ISR/NCW[1] and SeBA/SBA[2]. First, the C4ISR/NCW area will place increasing emphasis upon interfacing operational C4ISR systems to M&S, and this is the focus for the next NATO M&S Conference to be held in Turkey in approximately one year's time. Secondly, the increasing role of SeBA/SBA within Defence organisations will require the interfacing of M&S across the entire acquisition life-cycle, and associated knowledge management and ownership issues will also need to be resolved.

Concerning Process issues, it was clear from the Conference that reusability of M&S (which is of paramount importance for improving cost-effectiveness) stems from reuse at the Conceptual Modelling phase, so standards must be developed for this. Moreover, validation of M&S demands that the suitability of the abstractions that are selected for our models are explicitly questioned; therefore, a higher-level phase above conceptual modelling will be needed, in order to understand the application domain in which our models will be used. Furthermore, the Conference had highlighted the need for cultural transformation, to enable the process changes associated with SeBA/SBA and M&S sharing & reuse, and this must be explicitly addressed if these initiatives are to be successful.

Finally, I wish to thank the Interpreters who coped extremely well with the variety of accents and speeds of delivery; the French hosts who provided the excellent facilities; the charming French hostesses; the technicians who ensured the correct functioning of the audio-visual equipment; and the NMSCO team.

I wish everybody a safe journey home.

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[1] Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance / Network Centric Warfare.

[2] Synthetic Environment Based Acquisition / Simulation Based Acquisition.

Address given at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

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Integrated systems	Mission System Simulation	Validation and Acquisition)

14. Abstract

The conference presented a series of papers in sessions that were designed to provide an overview of NATO-PFP/Industry/National - Modelling and Simulation Partnerships and Organisations. Other topics that were covered in the Conference included: Modelling & Simulation Practices and Policy, the Use of M&S to Support Operations (e.g. Training and Communication Systems), Future Trends in M&S (such as Virtual Forces and Artificial Intelligence, Gaming and Agent Technology), M&S Best Practices (such as Validation Verification & Accreditation (VV&A) and Standards).

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