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RESEARCH AND TECHNOLOGY ORGANISATION

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RTO MEETING PROCEEDINGS **MP-MSG-022**

C3I and Modelling and Simulation (M&S) Interoperability

(Interopérabilité entre le C3I et la modélisation et la simulation (M&S))

Papers presented at the NATO RTO Modelling and Simulation Conference held in Antalya, Turkey, 9-10 October 2003.

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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.

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C3I and Modelling and Simulation (M&S) Interoperability

(RTO-MP-MSG-022)

Executive Summary

The NATO Modelling and Simulation Group (NMSG) Conference (MSG-022) "Command, Control, Communications and Intelligence (C3) and Modelling & Simulation (M&S) Interoperability" was conducted in Antalya, Turkey from 9 to 10 October 2003. All sessions of the Conference were unclassified. The Conference audience of 128 persons included experts from NATO countries, Partners-for-Peace (PfP), as well as invited nations. Nineteen papers were selected for presentation. In addition, two keynote presentations and a capstone paper were given.

Interoperability of Command, Control, Communications and Intelligence (C3I) and Modelling & Simulation (M&S) systems is a necessary requirement for effective and efficient support of future military operations, including; procurement, acquisition, test and evaluation, training, and application of necessary functionality within the ongoing operation. In order to be able to support this task, a close understanding and knowledge of the software architecture, the communications protocols, possible interfaces, data and object models, and the management procedures used on the C3I and M&S side is mandatory.

The majority of the actual solutions are interface driven to link stove-piped developed legacy systems. The use of common reference models facilitating the necessary data alignment and information exchange is a first step to broader and reusable solutions. Newer systems with configurable interfaces making use of these technical potentials are pointing to the next set of solutions.

Although the number of engineering solutions linking C3I and M&S systems is relatively high, the amount of "documented lesson learned" is relatively small. Most solutions are ad-hoc, not following a common or general scheme. In order to establish a standard way – which increases reusability and collaboration and reduces costs and risks of affected projects and programmes – this has to change. Documentation of applied methods and procedures must be captured and evaluated.

Technical Reference Models (TRM), such as the one developed by the Simulation Interoperability Standards Organization (SISO), are applicable to NATO standards and will facilitate the perception of common migration paths and reusability of legacy components in future systems. National solutions can be mapped to these TRMs to facilitate joint and combined C3I system and federation planning.

The Command and Control Information Exchange Data Model (C2IEDM), which is the NATO Standard Allied Data Publication No. 32 (ADatP-32) and the Data Model of Choice for the Multinational Interoperability Programme (MIP) connecting NATO's Command and Control systems and the basis for various national C3I systems, is successfully used for data alignment in various national projects. C2IEDM was not only applied to C3I systems, but also to M&S data alignment. As the NATO Data Administration Group (NDAG) is already using the C2IEDM for data management for C3I systems, the extension to M&S systems is perceived as a valuable option.

Future interoperability standards will depend much more on commercial solutions than it has been the case in the past. New standards as the next generation of the Unified Modelling Language version 2.0 (UML 2.0), the Extensible Mark-up Language (XML), web services, and the Model Driven Architecture (MDA) are applicable to C3I systems as well as to M&S systems. They support actual developments to make use of internet technologies – which are in particular observable in the United States where the definition of development of the Global Information Grid (GIG) was recently initiated.

Finally, a closer relationship between the NATO M&S Group and the Simulation Interoperability Standards Organization (SISO), in particular the observation, and where appropriate, active participation in study groups and product development groups, is likely to support the process of gaining C3I and M&S interoperability effectively. A formal liaison – based upon the initial informal relationship established by Dr. Jean-Louis Igarza, first chief scientist of the NMSG – will ensure that the NMSG is aware of the latest developments of the simulation standardisation world and can influence the new standards by bringing in the NMSG requirements as early as possible, i.e., before the standards are established. A closer relationship with EUCLID projects also may be valuable.

In summary, the conference was very successful. State of the art solutions as well as ideas and requirements for necessary future research and development were presented and the views of the armed forces, industry, government, and academia were discussed. The papers presented during the conference provided a good overview of what has been done in NATO and NATO/PfP nations, what is the state of the art, and the next steps.

Interopérabilité entre le C3I et la modélisation et la simulation (M&S)

(RTO-MP-MSG-022)

Synthèse

Une conférence sur « L'interopérabilité du C3I et de la modélisation » a été organisée par le Groupe OTAN sur la modélisation et la simulation (NMSG), à Antalya, en Turquie, les 9 et 10 octobre 2003. Toutes les sessions de la conférence étaient non classifiées. L'assistance, au nombre de 128 personnes, comprenait des spécialistes des pays membres de l'OTAN, des pays du PfP, ainsi que des pays invités. Dix-neuf communications ont fait l'objet d'une sélection. En outre, deux discours d'ouverture et une allocation de clôture ont été prononcés.

L'interopérabilité entre les systèmes de commandement, contrôle, communications et renseignement (C3I) et les systèmes de modélisation et de simulation (M&S) est une condition indispensable au soutien réel et efficace des futures opérations militaires, à savoir : approvisionnement, acquisition, essais et évaluation, entraînement et mise en œuvre des fonctions nécessaires dans le cadre des opérations en cours. Le soutien de l'interopérabilité passe par une bonne compréhension et une connaissance approfondie des architectures logicielles, des protocoles de communication, des interfaces possibles, des modèles de données et d'objets, ainsi que des procédures de gestion utilisées pour le C3I et la M&S.

La majorité des solutions actuellement proposées font appel à des interfaces pour établir des liens entre systèmes classiques distincts. Dans un premier temps, la mise en œuvre de modèles de référence commune, facilitant l'échange et l'alignement des données nécessaires ouvrirait la voie à des solutions réutilisables plus générales. Des systèmes plus récents, dotés d'interfaces configurables qui exploitent ces possibilités techniques, laissent prévoir de nouvelles solutions.

Malgré l'abondance relative de solutions techniques s'appliquant au C3I et à la M&S, relativement peu de documents existent sur "les enseignements tirés" de cette expérience. La plupart des solutions sont du type *ad hoc,* et ne suivent pas un schéma commun ou général. Cette situation doit changer en faveur d'une approche standard – qui donnerait plus de possibilités de réutilisation et de coopération et permettrait de réduire les coûts et les risques pour les projets et les programmes affectés. Il faudra saisir et évaluer les méthodes et procédures à appliquer.

Des modèles de référence techniques (TRM), comme celui développé par l'Organisation de normalisation de l'interopérabilité en matière de simulation (SISO), sont applicables aux normes de l'OTAN et faciliteront la perception de chemins de migration communs, ainsi que la réutilisation d'éléments classiques dans les systèmes futurs. Des solutions nationales peuvent être établies en fonction de ces TRM afin de faciliter la conception de fédérations et de systèmes C3I interarmées et multinationaux.

Le modèle d'échange d'informations de commandement et contrôle (C2IEDM), matérialisé par la publication normalisée ADatP-32 de l'OTAN, qui est le modèle de données de choix du Programme d'interopérabilité multinationale (MIP) reliant les systèmes de commandement et contrôle de l'OTAN, ainsi que la base de différents systèmes C3I nationaux, a été mis en œuvre avec succès pour l'alignement des données dans le cadre de plusieurs projets nationaux. Le C2IEDM n'a pas été appliqué uniquement à des systèmes C3I, mais aussi à l'alignement de données M&S. Etant donné que le Groupe pour l'administration des données de l'OTAN (NDAG) utilise déjà le C2IEDM pour la gestion de données de systèmes C3I, son extension aux systèmes M&S est perçue comme une option intéressante.

A l'avenir, les normes d'interopérabilité dépendront beaucoup plus de solutions commerciales que par le passé. Les nouvelles normes, telles que la prochaine génération du Langage de modélisation unifié Version 2.0 (UML 2.0), le Langage de balisage extensible (XML), les services du Web, et les Architectures guidées par modèle (MDA), sont applicables aux systèmes C3I ainsi qu'aux systèmes M&S. Ils supportent les développements actuels destinés à exploiter les technologies de l'Internet – qui sont surtout disponibles aux Etats-Unis, où le développement du Réseau global de l'information (GIG) à récemment été lancé.

La création de liens plus étroits entre le groupe M&S de l'OTAN et l'Organisation de normalisation de l'interopérabilité en matière de simulation (SISO), et en particulier l'observation, ainsi que, le cas échéant, la participation active à des groupes d'étude et des groupes de développement de produits, permettrait de faire avancer l'interopérabilité efficace entre le C3I et la M&S. Une liaison officielle – basée sur les relations officieuses établies par le Dr. Jean-Louis Igarza, le principal expert scientifique auprès du NMSG – permettra au NMSG d'être informé des derniers développements dans le domaine de la normalisation de la simulation. Le groupe pourra ainsi faire valoir ses souhaits en matière de normalisation avant l'établissement des normes. Il serait sans doute intéressant aussi d'établir des liens avec des projets EUCLID.

Pour résumer, la conférence a été très réussie. Des solutions faisant appel à des techniques de pointe ont été présentées, ainsi que des propositions et des besoins en matière de projets de recherche futurs. Les points de vue des militaires, des industriels, des représentants des gouvernements et des universitaires ont été débattus. Les communications présentées lors de la conférence ont fourni un bon aperçu des travaux réalisés dans les pays de l'OTAN, ainsi que dans les pays du PPP, de l'état actuel des connaissances et des initiatives qui restent à prendre.

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† Paper not available at the time of publishing

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Technical Evaluation Report
MSG-022/SY-003 Conference on
C3I and M&S Interoperability

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OVERVIEW

The NATO Modelling and Simulation Group (NMSG) Conference (MSG-022) "Command, Control, Communications and Intelligence (C3) and Modelling & Simulation (M&S) Interoperability" was conducted in Antalya, Turkey from 9 to 10 October 2003. All sessions of the Conference were unclassified. The Conference audience of 128 persons included experts from NATO countries, Partners-for-Peace (PfP) nations, as well as invited nations.

Out of the 30 submitted abstracts, 19 Papers were selected for presentation. In addition, two keynote presentations and a capstone paper were given. This technical evaluation report summarizes the core ideas and results presented in this wide variety of valuable contributions from NATO countries, PfP nations, and invited nations. In addition, for each category, the report provides an overview of the discussions conducted during the conference following each presentation.

INTRODUCTION

The importance of Modelling and Simulation (M&S) is now largely recognised within NATO. Among various military applications of M&S within the Alliance, Operational Support and Training are identified as high priority areas. In parallel NATO has developed an important activity in the Command, Control, Communication and Intelligence (C3I) Systems as the backbone support of military activities.

Whilst C3I and M&S domains have many technical similarities, they have developed along separate tracks in the Alliance, as in many nations, sometimes differing by their purposes and priorities. As an example, different standards have been developed in parallel and are not largely understood and shared in both communities. The NATO Modelling and Simulation Master Plan – the capstone document for M&S systems – does not mention the NATO C3 Technical Architecture – the capstone document for C3I systems – and vice versa. For the efficient support of planning, training, and executing of operations, as well as NATO procurement and doctrine development, this gap should be closed. Consequently, the main objective of this conference was to contribute to a better understanding of and an improvement in interoperability between C3I and M&S systems as a first step towards a common information technology (IT) infrastructure supporting M&S as well as C3I systems, thus, overcoming the shortfalls of interface driven solutions. Following topics were given as a guideline for the authors:

- Lessons learned from past experience in linking C3I and M&S,
- Current Joint use of C3I and M&S in Computer Assisted Exercises (CAX),

- Interoperability and data standards,
- Future projects.

In addition, the conference addressed the themes of research, development and cost-effective co-operative application of C3I and M&S systems. Furthermore, the Data Consistency and Translation between C3I and Simulations was perceived to be a first valuable step into this direction.

That these topics are generally of great interest can already be derived from the number of abstracts submitted following the call for papers. Twice the number of possible presentations was evaluated, and unfortunately not every valuable abstract could be accepted. The resulting paper selection consequently represents the leading edge of research, development, and application of methods, procedures and IT solutions supporting C3I and M&S Interoperability within NATO and PfP nations.

The Keynote speakers supported this perspective:

- Brigadier General B. Pekar, Turkish General Staff, stressed the necessity of appropriate training for efficient operational availability. Modelling and Simulation is the most economic and appropriate support to fulfil this requirement. The integration of Command and Control systems to enable "Train as they fight" is a cornerstone of realistic training. A tight relation between armed forces, industry and academia is necessary to support these efforts. The NATO fellowship programme, and in particular the Turkish Canadian cooperation in the C3I and M&S Interoperability domain, was stressed as another important factor by General Pekar.

- Dr. F. A. Yarman, General Manager of Havelsan, showed the potentials of the Turkish M&S market from the local defence industry to highlight the economic importance of the issue dealt with in this conference. He used the simulation based acquisition idea to show the benefits of using M&S stressing the importance of the scientific process of sound modelling. Synthetic environments, physical modelling, computer generated forces, and scenario generations, and after action review and replay were presented as the core domains of necessary military M&S efforts. C3I must be an integrated part of the resulting architecture. Furthermore, Dr. Yarman stressed the necessity of standards for effective reusability and collaboration and gave examples for migration procedures.

All presentations given during this conference perceived the role of M&S in Training and Education to be established, in particular the use of M&S for CAX. CDRE Jon Welch, NATO Allied Command Transformation (ACT), Norfolk, Virginia, U.S.A., presented the important new role of M&S in transformation in his capstone speech. NATO is transforming to fulfil its new mission. To steer the process and align sub-processes, the ACT is being established. Within the ACT, in particular Joint Education & Training and Joint Concept Experimentation will need M&S support and has C3I and M&S interoperability as a necessary requirement to fulfil the new tasks effectively and efficiently and to establish the envisioned NATO Transformation Process. In summary, M&S will play a pivotal role in transformation.

Within the following sections, the core ideas and discussion results are grouped by the topics given in the authors' guideline. When writing this technical evaluation report it was not intended to recite paper abstracts or give pure summaries, but to show the general developments and common ideas allowing the analyses of trends within NATO/PfP nations and other invited nations. Therefore, only the contributions to this objective are addressed in this report. As previously mentioned, all the papers are very valuable and it is highly recommended to read and analyse all underlying trends and references, in particular when dealing with special issues. The papers will be referenced using the numbers assigned in the official programme, such as [P-01] to reference to the paper "Overview of Recent Findings of the Study Groups of the Simulation Interoperability Workshop dealing with C3I and M&S Interoperability".

LESSONS LEARNED FROM PAST EXPERIENCES IN LINKING C3I AND M&S

The domain of linking C3I and M&S systems is recognized more and more as an engineering task in the NATO nations – and in non-NATO nations as well – and therefore lessons learned are now being generated. Examples of such lessons learned are summarized in [P-01] and [P-02]. However, a standard way to link C3I and M&S is not yet established. The SISO Technical Reference Model for C4ISR and Simulation System Interoperability presented in [P-01, P-18] is a first promising step, but actually most link solutions are "one of a kind" and in general not easily reusable.

Another often observed shortcoming is documented in [P-02], and the discussion showed the validity of these perceptions as well: In general, prototype developers are neither HLA nor C3I experts, which results in proprietary solutions. The use of standards is seldom the case with prototype developments, and unfortunately, many M&S systems in operational use are still on the prototypical implementation level. Standardization is often seen as something that can be dealt with later in the project, i.e., after the proof of feasibility. This procedure generally makes standardisation unnecessarily costly, as re-implementations and updates are more expensive than using the standard from the beginning of the project. In particular recommended or mandated standards, such as given in the NATO C3 Technical Architecture and the NATO M&S Master Plan, should already be used in the initialisation phase. The increasing use of testbeds with necessary integration capabilities may help to overcome this shortcoming.

However, it would be naïve to assume that coupling of C3I and M&S systems would be a pure engineering problem. Even if we could solve the linkage without additional challenges, the resulting solutions are not necessarily sufficient. This was pointed out in [P-09]. Actually, many M&S challenges have to be solved, such as multi-resolution challenges. The discussion showed furthermore, that increasingly multilevel-security challenges have to be solved as well.

For coping effectively and efficiently with C3I and M&S interoperability issues, deep knowledge of IT architectures, data and object models, and applied management procedures of both communities is mandatory. A good overview of most relevant NATO C3 interoperability standards and the applicability of respective reference models are given in [P-18]. The standards referred to in this paper are a minimal set of necessary knowledge of M&S experts responsible for NATO C3I and M&S interoperability.

CURRENT JOINT USE OF C3I AND M&S IN CAX

The M&S application domain of training and education, in particular Computer Assisted Exercises (CAX), is likely to be the most visible mature application for NATO. Keynotes and presentations supported this view.

In [P-02] the NATO CAX "Cannon Cloud 2002" was evaluated to illustrate the use of C3I and M&S within NATO for training and education. Cannon Cloud 2002 successfully demonstrated the utility of integrating entity-level simulations into an operational level CAX using distributed techniques. [P-02] used Cannon Cloud 2002 as a case study highlighting the main domains of C3I and M&S interoperability, which includes typical simulation-to-simulation challenges, such as aggregation and other multiple resolution issues. The similar national use of C3I and M&S supporting CAX was the topic of various papers, including [P-05, P-06, P-09].

NATO politics require that NATO partners and allies participate in common exercises. Logically, new NATO partners and PfP nations use CAX to gain experience in the application of NATO doctrine and procedures. [P-06] shows how this has been done in Slovakia in an exemplifying way. These new CAX systems and federations are normally planned with the purpose of distributed use and integration with other NATO/PfP national centres.

The gateway solution connection between C3I and M&S applications prototypically implemented for the Royal Army of the Netherlands as presented in [P-09] can be seen as a state of the art implementation of C3I and M&S interoperability. Although common infrastructures are envisioned for future applications, interfaces like this are likely to be the rule for the mid term future. Similar approaches can be found in various national examples (see, e.g. [P-01]).

It should be pointed out, that some papers, e.g. [P-05, P-09, P-11], are dealing with the potential and ongoing research to use M&S within C3I systems to support the operational decision making process by applying M&S in the harmonized suite of decision support systems. Although the technical challenge to couple C3I and M&S is at least comparable to CAX, the requirements to be fulfilled by the M&S systems to support real operations are higher than for the application within training and education. Credibility of the M&S application and the necessary Verification and Validation was mentioned in the discussions.

INTEROPERABILITY AND DATA STANDARDS

In the discussions following various presentations on interoperability and data standards it was pointed out – in particular from the academia present at the conference – that data exchange is necessary for C3I and M&S interoperability, but not sufficient. While actual standards and solutions are targeting the implementation level, meaningful interoperability can only be reached on the modelling level. Actually, the modelling level is aligned by additional procedures to follow when setting up federations (as documented in the Federation Development and Execution Process). The results of the Simulation Interoperability Standards Organization (SISO; see http://www.sisostds.org) Study Groups are supporting this perception [P-01]. New standards will take this into account, such as the Model Driven Architecture (MDA) approach of the Object Management Group (OMG; see http://www.omg.org/mda). In the section on Future Projects, some additional information concerning the applicability of these new standards for NATO M&S, C3I, and C3I and M&S interoperability will be given.

The use of a common source to initialise C3I and M&S systems is one of the most obvious uses of common data standards. The second immediately obvious use is the sharing of information by using standardized shared data elements. Both ideas were part of the presentation of the French project ESTHER [P-05]. For the initialisation, XML documents are created from the ESTHER data source. All participating systems and components are able to map the XML tagged information to their own presentation. The NATO Reference Database presented as part of [P-02] is also pointing into this direction. The same approach is furthermore used for the German Integrated Army Modelling and Simulation Data Network [P-08]. It is of special interest that the NATO Command and Control Information Exchange Data Model (C2IEDM, NATO Standard ADatP-32) was enhanced and extended for this purpose following the C2IEDM extension rules. Generally, data interoperability is seen as a necessary precondition for C3I and M&S interoperability, and using an established C3I originated data model as the generic hub will support the vision of C3I and M&S interoperability more efficiently than it would be the case using a proprietary or newly developed data model.

The Extensible Mark-up Language (XML) is used in various applications with great success, examples given during this conference can be found in [P-05, P-08, P-11]. However, the use of XML doesn't ensure interoperability per se, but that management of the tags used for the exchange of information is mandatory. The actual namespace management of the C3I community therefore must be reflected, or – where possible – used for XML based data information share. Potential future mark-up languages, such as the recently introduced Simulation Reference Mark-up Language (SRML; see www.w3.org/TR/SRML/), will support interoperability. However, without being accompanied by aligned management processes, meaningful interoperability cannot be reached.

HLA is not the only method of choice to reach interoperability between C3I and M&S. The use of open and commercially supported interoperability enablers was presented in various papers. In particular, the use of Internet technologies [P-10], Extensible Mark-up Language (XML) [P-12], Unified Modelling Language (UML) [P-14] and the Common Object Request Broker Architecture (CORBA) [P-13] should be mentioned. The Model Driven Architecture (MDA) of the Object Management Group (OMG) is supporting all these solutions and seems to have the potential to become the overarching coordinating approach. These approaches are not mutual exclusive but complementary with huge overlaps. A common overarching principle, such as the MDA, enables the community furthermore to generalize enhancements and extension, such as that recommended for UML in [P-14]: contrarily to having this valuable work available only in UML, the approach to align the various techniques using the MDA allows the reflection of the results in neighboured methods as well. As MDA is applied in C3I development, there seems to be a good applicability of the MDA to C3I and M&S interoperability issues. Furthermore, the migration to web enabled solutions is supported by the MDA, so that new developments in the C3I community, in particular the Global Information Grid (GIG, see U.S. DoD Directive 8100.1), can be coped with.

Modelling issues dealt with in this conference will support the identification of necessary levels of interoperability as well as critical connections between C3I and M&S. In the mid term future, approaches such as presented in [P-15, P-16] will enable the evaluation of C3I architectures as well as C3I and M&S architecture before these are established and will support the definition of necessary information exchange requirements as well as process harmonization requirements. In the long term, better and even automatic support may become an option if software agents can make use of these architecture models effectively and efficiently. To this end, however, meta-data of the models of the C3I and M&S architecture are needed describing the reliability of the data, constraints and assumptions of the model, pedigree of data and models, and the other meta-data as exemplarily specified in the NATO Code of Best Practise for Command and Control Assessment (see http://www.dodccrp.org/nato_supp/nato.htm). Examples helping to answer the question why such data and meta-data are so important are given in [P-17] dealing with essential precondition for coupling model based information systems. Furthermore, the paper shows that interoperability of models is often a matter of the alignment of the conceptual models, not the implementation level. The fact that two models can be linked to exchange “bits and bytes” doesn’t imply that the resulting federation operationally makes sense. For meaningful interoperability, the conceptual models must be mapped to each other as well. The domain of “composability” dealt with under the umbrella of SISO and DMSO also contributed to the discussion. Meaningful interoperability on the implementation level requires composable models on the conceptual level.

FUTURE PROJECTS

The use of new standards and their applicability to NATO/PfP M&S, C3I, and C3I and M&S interoperability was the topic of various discussions. Explicitly mentioned were the Model Driven Architecture (MDA) developed by the Object Management Group, Web Services, and the Extensible M&S Framework (XMSF). As previously mentioned, the actual M&S standards Distributed Interactive Simulation (DIS) and High Level Architecture (HLA) are targeting the implementation level while meaningful interoperability requires alignment on the conceptual level. The various levels of system interoperability are defined in [P-08] and the definition is supported by ongoing work within academia and industry. A common ontology is the objective of various projects initiated by several nations; examples are given in [P-01, P-05, P-08, P-09]. Data Repositories and M&S Repositories, as mentioned in [P-02, P-12, P-19], are a step into the right direction, but to establish an aligned approach; the establishment of a coordination organization is necessary. To reach this goal, [P-09] recommends the development of a “Master Plan” to align the software architectures and the data/object models supporting NATO C3I and M&S interoperability. The analyses of national contributions and conducting additional feasibility studies under aegis of the NMSG are valid options for future projects.

Additionally to this technical research and development, action on the bureaucratic side is also needed, e.g., capability packages and requirement analysis for actual C3I solutions and possibly future STANAG development must be addressed concerning C3I and M&S interoperability. Examples how this is done in the domain of Tactical Missile Defence are given in [P-02]. In particular the Missile Defence Testbed Vision is a valuable example of common requirement derivation and analyses. An example of how this was done for STANAG development for low-level tactical data exchange is given in [P-12]. This paper also comprises a list of challenges to achieving low level tactical data exchange, which can easily be generalized for C3I and M&S interoperability. Additionally, recommendations for other actions concerning the alignment of NC3TA and M&S activities and the use of the SISO C4ISR/Sim Technical Reference Model within the NATO standard are given in [P-18].

One key enabler of new infrastructures is the existence of migration concepts for legacy solutions. The ESTHER project of the French Armed Forces [P-05] shows one possible way to integrate Live, Virtual, and Constructive C3I and M&S systems using common standards for new component development as well as wrapping and interfacing legacy systems. Although the discussions showed that there are alternatives, the example given in this paper is state of the art and can serve as a general example.

Although not directly connected to the challenge of C3I and M&S interoperability, the Training and Education Enhancement Programme (TEEP) [P-03] will influence the future development. TEEP comprises – among other valuable issues – interoperability challenges to support primarily Partnership-for-Peace (PfP) efforts. Objective is the establishment of a multinational learning environment in support of interoperability between allies and partners, including various CAX, and integrating Advanced Distributed Learning (ADL) and Simulation. In support of this, SACLANT/ACT has been established as the single focus to organize and coordinate NATO/PfP efforts and harmonise it with national efforts. In which way this will influence future developments is open, but without doubt the alignment of necessary participating standards – such as the High Level Architecture (HLA), the Synthetic Environment Data Representation and Interchange Specification (SEDRIS), and the Shareable Content Object Reference Model (SCORM) – will be a main issue.

The use of the Internet for future Advanced Distributed Simulation Systems solutions was the core idea presented in [P-10], focussing on Peer-to-Peer (P2P) applications. The NetSim project of the Swedish Defence Research Agency is analysing the usability of HLA standards in this new environment. In the United States, the Extensible M&S Framework (XMSF, see http://www.movesinstitute.org/xmsf) group is doing related similar research. Leading experts see "M&S as the next killer application on the Web" (as stated by Dr. Anita Jones on 6. September 2002 during the XMSF Symposium at George Mason University, Fairfax, Virginia, U.S.A.). Future projects are likely to make use of these technologies. This vision is supported by the ideas comprised in [P-19], presenting an overview of the European Co-Operation for the Long-term in Defence (EUCLID) RTP 11.13. The products and results are published on http://www.euclid1113.com. An analysis of the usability of their results in the domain of NATO C3I and M&S interoperability may be valuable. As EUCLID RTP 11.13 is tightly related to web based distribution of M&S application based on the concepts of the High Level Architecture (but not necessarily limited to its implementation), this should be technically feasible with minimal effort; however, the contractual issue may become an obstacle.

SUMMARY AND RECOMMENDATIONS

Interoperability of C3I and M&S systems is a necessary requirement for effective and efficient support of future military operations, including procurement, acquisition, test and evaluation, training, and application of necessary functionality within the ongoing operation. In order to be able to support this task, a close understanding and knowledge of the software architecture, the communications protocols, possible interfaces, data and object models, and the management procedures used on the C3I and M&S side is mandatory.

The majority of the actual solutions are interface driven to link stove-piped developed legacy systems. The use of common reference models facilitating the necessary data alignment and information exchange is a first step to broader and reusable solutions. Newer systems with configurable interfaces making use of these technical potentials are pointing to the next set of solutions.

Although the number of engineering solutions of linking C3I and M&S systems is relatively high, the amount of "documented lesson learned" is relatively small. Most solutions are ad-hoc solutions, not following a common or general scheme. In order to establish a standard way – which increases reusability and collaboration and reduces costs and risks of affected projects and programmes – this has to change. Documentation of applied methods and procedures must be captured and evaluated.

Technical Reference Models (TRM), such as the one developed by the Simulation Interoperability Standards Organization (SISO), are applicable to NATO standards and will facilitate the perception of common migration paths and reusability of legacy components in future systems. National solutions can be mapped to these TRMs to facilitate joint and combined C3I system and federation planning.

The Command and Control Information Exchange Data Model (C2IEDM), which is the NATO Standard Allied Data Publication No. 32 (ADatP-32) and the data model of choice for the Multinational Interoperability Programme (MIP) connecting NATO's Command and Control systems and the basis for various national C3I systems, is successfully used for data alignment in various national projects [P-08]. C2IEDM was not only applied to C3I systems, but also to M&S data alignment. As the NATO Data Administration Group (NDAG) is already using the C2IEDM for data management for C3I systems, the extension to M&S systems is perceived as a valuable option.

Future interoperability standards will depend much more on commercial solutions than it has been the case in the past. New standards as the next generation of the Unified Modelling Language version 2.0 (UML 2.0), the Extensible Mark-up Language (XML), web services, and the Model Driven Architecture (MDA) are applicable to C3I systems as well as to M&S systems. They support actual developments to make use of Internet technologies – which are in particular observable in the United States where the definition of development of the Global Information Grid (GIG) was recently initiated.

Finally, a closer relationship between the NATO M&S Group and the Simulation Interoperability Standards Organization (SISO), in particular the observation, and where appropriate, active participation in Study Groups and Product Development Groups, is likely to support the process of gaining C3I and M&S interoperability effectively. A formal liaison – based upon the initial informal relationship established by Dr. Jean-Louis Igarza, first Chief Scientist of the NMSG – will ensure that the NMSG is aware of the latest developments of the simulation standardisation world and can influence the new standards by bringing in the NMSG requirements as early as possible, i.e., before the standards are established. A closer relationship with EUCLID projects also may be valuable.

In summary, the Conference can be perceived as very successful. State of the art solutions as well as ideas and requirements for necessary future research and development were presented and the views of the armed forces, industry, government, and academia were discussed. The papers presented during the conference provided a good overview of what has been done in NATO and NATO/PfP nations, what is the state of the art, and the next steps.

Paper presented at the MSG-022/SY-003 Conference on "C3I and M&S Interoperability",
held in Antalya, Turkey, 9-10 October 2003, and published in RTO-MP-MSG-022.

NATO Annual Modelling and Simulation Conference

"C3I and Modelling and Simulation Interoperability"

Introduction

Mr Graham G. BURROWS, Head, NMSCO
Conference Committee Chairman
RTA - BP 25
92201 Neuilly sur Seine, 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 4th NATO Modelling and Simulation Group Conference. The Theme of this years Conference is; "C3I and Modelling and Simulation Interoperability" The importance of M&S has been recognised within NATO now for a number of years and among one of the key applications has been to provide support for military operational planning and in exercising and training. But key to this support has been the linking of Models and Simulations to the many and diverse C3I systems that we encounter within NATO and our PfP Partners so that we may indeed adopt the paradigm " train as you fight" . And so the objectives of this Conference are to contribute to a better understanding of and an improvement in interoperability between M&S and C3I systems. 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, as always, 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 –
Colonel Z. Ipekkan; Col. M Finnern; Mr Hans Jense; Mr Andy Fawkes; and Mr Brian Witherden.

These gentlemen will also be very firm with timekeeping, and I have issued red cards to be flashed to any of our presenters that stray over their allotted time.

I would also like to introduce Dr. Andreas TOLK. Andreas is a visiting professor at the USA Virginia Modelling, Analysis and Simulation Centre. He has been very active in M&S for many years and has made great contributions particularly in the Command and Control Systems field. Andreas has agreed to perform a very useful function at our Conference that of the Technical Evaluator. He 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 Turkish hosts for providing these excellent facilities, and their superb overall support.

Enjoy the Conference, in particular the Papers, please also make use of the breaks for side discussions, and enjoy Antalya. You are here in a beautiful part of the world at a particularly attractive autumn period – I hope the weather will be kind to you.

Host Nation Welcome Address

(9 Oct 2003)

Colonel Z. IPEKKAN
Deputy chief of Turkish general staff
Scientific Decision Support Center
Host Nation Coordinator and NMSG TU Principal Member
06650 Bakanliklar, Ankara, Turkey

Commanding officer, distinguished representatives of NATO and PfP nations, good morning.

I am Colonel Ziya IPEKKAN, Deputy Chief of Turkish General Staff Scientific Decision Support Center.

Firstly, I would like to express my great pleasure for hosting you today and tomorrow in this beautiful city of Turkey for C3I and M&S Interoperability symposium 2003. Welcome you all to Antalya !
It is a great pleasure for me to announce to you that we are very proud to host another RTO activity during this week, a Lecture Series on Biological and Chemical Warfare in Istanbul which is one of the unique cities of the world.

We put great emphasis on activities carried out by NATO RTO Panels/Groups and make use of every opportunity to take active roles in their studies. We believe that hosting such activities like this symposium and the lecture series in Istanbul is one of the most prominent indicators of our resolution.
Now, I would like to give you some information on this beautiful city where we are holding this symposium.
Before it came under the Ottoman sovereignty that founded in 1299, Antalya region was controlled by Hittites, Lydians, Persians, Seljuks and Byzantines.
Antalya is located in the Mediterranean region, which is one of the seven regions of the republic of Turkey. The population of the city is around 1,5 million. Antalya is considered to be the tourıstıc capital of Turkey and the east Mediterranean with its all year long sunny skies, unique natural beauties, magnificent beaches lapped by clear blue waters and historical wealth. This city is located on such a rare geography of the earth that it is possible to ski and swim on the same day.
After this brief information on Antalya and its history, I would like to touch on a couple of points about Turkish armed force's view about modelling and simulation domain. Brigadier General PEKAR wall give you more detailed information on this issue shortly after this presentation.
Due to ever increasing complexity of the operational environment and shrinking defense budgets, like every other nation, Turkey is being forced to act wisely in all of its activities. Within this context, the importance and usefulness of modelling and simulation systems has been well comprehended by Turkish armed forces and most of the emphasis has been put on acquiring educated personnel and developing suitable platforms for enhancing cooperation among Turkish armed forces, universities and industry. As a consequence of these efforts, the contribution of modelling and simulation systems to training, analyses and acquisition functional areas is increasing day by day.

Finally, once again I would like to express our pleasure for hosting you in this unique city for the NATO Modelling and Simulation symposium 2003. I hope we experience a very fruitful two days.

Turkish Military Keynote Address

Brigadier General B. Pekar
Head of Scientific Decision Support Center of Turkish General Staff
TR 06100 Bakanliklar, Ankara
Turkey

Good morning ladies and gentlemen,

First I would like to express that it is a privilege and a great pleasure for us to host this symposium and the distinguished community of NATO. Welcome to you all!

As the Head of the General Staff Scientific Decision Support Center, I would like to express my personal views about:

- The importance and application areas of the modeling and simulation activities for the Turkish armed forces, and
- How to improve the effectiveness and the efficiency in modeling and simulation activities, specifically in the common ground of NATO.

Within the limits of the defense budget, we focus our efforts to fulfill our needs for:
- Conducting the defense planning and management activities while keeping pace with the rapid developments of this information age,
- Training our military personnel to have the ability to use all those state-of-the-art defense systems efficiently and effectively, and
- Preparing the forces for every type of mission, including the NATO or United Nation's peace operations in different crisis regions of the world, which the Turkish armed forces has never refrained from participation.

Due to environmental and financial constraints, the activities and resources required to fulfill those needs have confronted with being reduced. These conditions have required the intense application of study-analysis-decision making process in every aspect of the defense planning and management activities.
Since field experimentations and live exercises cause environmental pollution, and have a high cost, it becomes necessary to lessen the number of practices, and to look for different, specifically economic, ways of meeting needs for experimentation and training.
At this point, modeling and simulation systems come forward as a rapid and economic tool.
In this respect, we believe that exploiting the modeling and simulation systems is one of the primary requirements to conduct the activities effectively for concept development, determinating capability gaps, system definition to meet capability lacks, systems acquisition, personnel / unit training, exercises, and operations analyses within given constraints.

Consequently, we actively participate in every NATO activities related with modeling and simulation, while enhancing our national assets and capabilities in this respect.
Since 1996 when the NATO modeling and simulation group was established, Turkish armed forces have been steering the capabilities of the national universities and the defense industry to contribute to developing alternative solutions to problems encountered in defense matters.
In this respect, the Turkish armed forces modeling and simulation seminar held nationwide in 1998 was the first attempt in enhancing national modeling and simulation capabilities.
More than 500 attendees from different national universities, public or private sector foundations, research centers, and corporations participated in that seminar.
During 13 parallel sessions of the seminar, 58 papers were presented, 17 corporations made demonstrations, modeling and simulation national policy, existing and required capabilities were addressed.

As a consequence, in order to institutionalize the modeling and simulation activities related with personnel training, the war gaming and simulation center was founded in the Turkish armed forces war college in 1998.

In this center, the main goal is to provide models and simulation systems as a tool exploited in personnel education and training.

In 1999, we founded modeling and simulation laboratories in the Middle East Technical University and Istanbul Technical University.
The main objectives of those laboratories are:

- To make fundamental and applied research
- To develop models and simulation systems for providing solution alternatives to the common problems of different services,
- To combine the efforts and the capabilities of industry, university, and armed forces,
- To establish organizational knowledge-base, and
- To institutionalize the collaboration activities.

In parallel to those activities, our universities, like the Middle East Technical University, have recently founded techno-cities within their campus areas. In those techno-cities, subject matter experts and technical professionals from different scientific / engineering disciplines and defense industry site can find the opportunity to exchange know-how and enhance knowledge in development programs.
We believe that those techno-cities can provide utilities and facilities in service of the NATO modeling and simulation community.

In 2000, we established the scientific decision support centers and units in the main headquarters of the services and the general staff in order to provide decision support to high level decision makers, and to coordinate modeling and simulation activities related with employment and infrastructure initiatives.
In accordance with the decision support centers and units, the Turkish armed forces modeling and simulation coordination and consultation boards were established in order to coordinate the M&S efforts from the joint point of view.
During the last five years, postgraduate studies related with M&S in different national and international universities have been provided to more than 100 personnel and those personnel were assigned to the posts in accordance with their academic backgrounds.
In cooperation with Turkish armed forces, the Middle East technical University started a postgraduate program specifically in modeling and simulation. The scholars have chance to make their researches and thesis studies in the modeling and simulation research and application center in the same campus. We believe that this postgraduate program can serve for the needs of the NATO nations as well.
There are also defense institutes in our army, navy, and air force academies for officers to make scientific, fundamental and applied research.
Turkish armed forces also makes contributions to the efforts of NATO studies, analysis, and simulation panel. Recently there were two working groups lead by Turkey in the NATO SAS Panel.
While enhancing the modeling and simulation capabilities in parallel to the developments in M&S domain, it is also necessary to spend effort to disseminate those capabilities among the services and personnel in the application domain.
We believe that the accreditation, verification and validation activities for models, simulation systems, and certification of data used in M&S applications are the essential driver efforts for M&S to be accepted and exploited by the M&S user communities throughout the armed forces. Our efforts in this respect are still ongoing.
Canada and Turkey have been collaborating in the M&S through the NATO fellowship program, which has been actively used for at least 15 years. We have been observing that these kinds of collaborations also serve in establishing a common M&S culture and in exchanging M&S knowledge between nations. We strongly recommend that other NATO nations participate in and provide NATO fellowship programs among each other.

We also believe that various research centers in NATO countries can be guided by the NATO MSG to establish cooperation between them with respect to the needs of NATO. We consider that our establishments are ready and eager to take place in such collaboration.

In the light of the global changes and developments, the theme of the symposium, which is "C3I and Modeling and Simulation Interoperability", has a particular significance among all others.
Modeling and simulation systems used in redefining new threats, which has been uncertain as a consequence of 9/11, and in determining new operations forms against that new threat, should certainly cover command and control matters with a required level of detail.
Thus, we believe that the interoperability between C3I models and other simulation systems is one of the indispensable requirements for new system developments.
During this symposium, four different papers will be presented by Turkish authors. Those papers will address the findings and issues that come out from development and research projects about modeling and simulation of operation command centers, modeling of border security and control systems, graphical interface software developments for war games, and modeling command and control. Those four development and research projects were conducted with the cooperation of industry, university and the Turkish armed forces.
It is certain that NATO nations will have a chance to share their knowledge and experience on M&S during this symposium. We believe that this invaluable activity will provide the opportunity to exchange information that can help us avoiding duplication of efforts, and determining the issues we should focus and / or aggregate our efforts on.
For organizing this invaluable symposium, I would like to thank the NATO Modeling and Simulation Group, which carry the burden and the responsibility of guidance and coordination in use and enhancement of M&S technologies among NATO nations.

Finally, once again I would like to express our pleasure for being the host nation of the 2003 NATO Modeling and Simulation Symposium, to say "welcome you all in Turkey", and I wish you all have a good time and enjoy your stay in Antalya.

Thank you.

KEYNOTE ADDRESS

Potentials of Turkish Modeling and Simulation Market from Local Defense Industry

Dr. Faruk A. Yarman
General Manager
HAVELSAN

Click here to view PowerPoint presentation; Press Esc to exit

Paper presented at the MSG-022/SY-003 Conference on "C3I and M&S Interoperability", held in Antalya, Turkey, 9-10 October 2003, and published in RTO-MP-MSG-022.

Overview of Recent Findings of the Study Groups of the Simulation Interoperability Workshop dealing with C3I and M&S Interoperability

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OVERVIEW

The Simulation Interoperability Standards Organization (SISO), in particular the Planning and Review Panel (PRP) on Command, Control, Communications, Computers, and Intelligence (C4I), deals intensively with the topic of M&S and C3IInteroperability over the recent Simulation Interoperability Workshops (SIW) which are taking place in the Spring and in the Fall every year in the United States. Since 2001, a European SIW also occurs every summer in Europe in various places.

The SISO C4I Forum addresses primarily the modelling and simulation of Command, Control, Communications, Computers, and Intelligence (C4I) systems in constructive, virtual, and live environments, the coupling of real C3Isystems and simulation systems for computer assisted exercises (CAX), and support for operations. Additional focus: Development of a Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Technical Reference Model (TRM), a common framework for C4ISR system-to-simulation interoperability, and relationships among international C4ISR architectures. It sponsored two study groups, namely the Study Group on "C4I Study Group" (March 1999 – September 2000) and the Study Group on "C4ISR/Simulation Technical Reference Model Study Group" (March 2001 – September 2002), which results and related underlying, parallel, and future papers will be presented within this paper. The second Study Group will present the results of additional work during the SIW in Fall 2003, among others in form of a "C4ISR/Simulation Interoperability Source Book."

1 INTRODUCTION

The Simulation Interoperability Standards Organization (SISO) is dedicated to the promotion of modelling and simulation interoperability and reuse for the benefit of diverse M&S communities, including developers, procurers, and users, world-wide. SISO originated over ten years ago. The initial conferences rapidly on general simulation interoperability evolved into the Distributed Interactive Simulation (DIS) Workshops. The DIS Workshops transformed in 1996 into a more functional organization called SISO participating actively in the standardization efforts related to the High Level Architecture (HLA). Today, SISO is concerned with all sorts of standard development and application facilitating interoperability between simulation systems as well as between simulation systems and real life systems.

SISO actually conducts three workshops per year, called the Simulation Interoperability Workshops (SIW). Two SIW are conducted in the United States, the Spring SIW and the Fall SIW. In addition, one European SIW is conducted in summer.

Paper presented at the MSG-022/SY-003 Conference on "C3I and M&S Interoperability", held in Antalya, Turkey, 9-10 October 2003, and published in RTO-MP-MSG-022.

The scope of the Workshop encompasses a broad range of simulation issues and communities, including military applications as well as other government and non-government applications. Workshop participants include simulation developers, simulation users, and operations analysts, from various government, industry, and academic communities. The Workshop focuses on issues involving distributed interoperable and composable simulations, reusable components, and on the development of a common process model for designing, composing, executing, and analysing the results of simulations, as articulated in the High Level Architecture (HLA) for Modelling and Simulation. While HLA is definitely a cornerstone of SISO and SIW activities, the actual scope is broadening and new technologies supporting concepts of advanced distributed simulation are evaluated increasingly.

The SIW include tutorials, papers on state-of-the-art experiences, identification and discussion of interoperability issues, and presentation of proposed solutions. As these solutions are prototyped and demonstrated, they become candidates for possible standards within relevant simulation communities. Various workshop forums provide opportunities for user and technical communities to meet, share ideas and experiences, identify ways to make distributed simulation more effective and efficient, and support the development of appropriate interoperability standards. Of particular interest for the conference on "C3I and M&S Interoperability" is the forum on "Command, Control, Communications, Computers, and Intelligence (C4I)."

The C4I forum addresses standards to ensure interoperability when coupling simulation systems and C3Isystems, standards to ensure composability when integrating simulation components and C3Icomponents into a common framework, and standards to represent C3Isystems and the underlying infrastructure within simulation applications. Within this forum, papers are presented which are dealing with architecture and data/object model alignment, common frameworks, applicability of C3Istandards and open standards, and lessons learned from applying these standards. In particular, C3Isupports the development of enhanced operational functionality based on M&S, and especially on increasing the efficiency and abilities of the Warfighter by introducing simulation capabilities within operational systems.

The C4I forum sponsored two Study Groups dealing with interoperability of command and control systems and simulation systems. The role of a SISO Study Group is to prepare a domain for future standardization. To this end, the scope of the future standard has to be defined, time lines for perceived achievements are established, literature researches are done and evaluated, related SISO papers are analysed, and respective reports and supporting documentation are produced and disseminated. When successful and advanced enough, a Product Development Group will take up the work to establish a proposal for a new standard to enhance interoperability for simulation systems and live systems as envisioned in the SISO charter.

The first Study Group dealing with the general problem of command and control system to simulation system interoperability was called "C4I Study Group" and was conducted from March 1999 to September 2000. The second Study Group was called "C4ISR/Simulation Technical Reference Model Study Group" and started in March 2001. The final report of this second group was delivers in September 2002; however, it was also perceived that much more work needed to be done before a Product Development Group could be established. Therefore, the Study Group members decided to work on additional follow-on products under the aegis of the C4I forum. The next report will be delivered during the Fall SIW 2003 to be conducted in September 2003 in Orlando, Florida, United States.

The author chaired the C4I forum of SISO during this period. Furthermore, he contributed actively to the resulting reports. He also published several papers dealing with this issue, some of them having been awarded by SISO.

However, this paper gives his personal view on the problem domain and the achievements of the resulting reports of the Study Groups. The findings in these papers are therefore individual interpretations, and neither do they reflect the official view of the Virginia Modeling Analysis and Simulation Center, nor the view of the SISO or any sponsors of the related efforts.

2 DEFINITION OF THE UNDERLYING PROBLEM

The NATO Modelling & Simulation Master Plan (NMSMP) [1] defines various domains of simulation system applications, which implicitly demand the integration of simulation systems into command and control systems or vice versa, e.g., to conduct computer assisted exercises (CAX) and to deliver simulation based support to operations. Interoperability of these two families of systems is furthermore necessary to reach the Objectives and Subobjectives of the NMSP, as stated in table 1.

Table 1: Objectives and Subobjectives in the NATO Modelling & Simulation Master Plan

Objective 1	Objective 2	Objective 3	Objective 4	Objective 5
Establish a Common Technical Framework	**Provide Common Services in NATO M&S**	**Develop Simulations**	**Employ Simulations**	**Incorporate Technical Advances**
1.1 Adopt HLA	2.1 Compile M&S Information	3.1 Identify & Prioritise Requirements	4.1 Plan Employment	5.1 Monitor M&S related Advances
1.2 Establish Data Interchange Standards	2.2 Provide M&S Education	3.2 Identify Strategies	4.2 Provide Resources	5.2 Conduct Research & Development
	2.3 Establish a Simulation Resource Library	3.3 Allocate Resources	4.3 Provide Databases	5.3 Share Information
	2.4 Establish a Help Desk	3.4 Execute Strategy	4.4 Operate Simulations	5.4 Implement Advances
		3.5 Provide Feedback	4.5 Conduct Impact Assessment	

As stated in [2], one of the shortcomings of the NMSG is that he is not connected, aligned, or harmonized with the NATO Consultation, Command and Control (C3) Technical Architecture (NC3TA) [3]; neither is the NMSG integrated into the NC3TA.

In other words: Both communities – C3I and M&S – are using the same or very similar information technology (IT) and the same commercially driven solutions for underlying operations, such as filing, networking, messaging, databases, etc.; however, the applications of both communities have been developed in a stove-piped manner without knowledge of the other sides efforts (and often not even with the knowledge of the efforts of the same community). Unfortunately, as the discussions with the participants in the Study Groups showed, this observation is true all over the world, last but not least in leading countries of NATO, such as the France, Germany, the United Kingdome, and the United States.

The result is generally an interface driven solution, such as categorized in [4]. Most of these interfaces are based on ad-hoc efforts, leading to rigid information infrastructures, double efforts, the permanent reinvention of the wheels, and systems with interfaces as much as potential partners. This solution is not satisfying. Consequently, alternative approaches were proposed since several SIW. They can be divided into three broad categories:

- The first group is primarily focussed on the coupling of command and control systems with simulation systems based on the idea of standardized interfaces, or at least common reference models to be used for the development of these interfaces.

- The second group tries to reuse more or less already established and/or standardized components and solutions to enhance C3I-to-M&S Interoperability. These components are primarily found in the C3I domain, such as Common Message Providers, or data models used for automatic database replication mechanisms.

- The third group is interested in setting up a common infrastructure for military IT to be used by the C3I community as well as the military M&S community. In particular the use of common commercial solutions, open standards, or even open sources could facilitate this objective, which needs to comprise migration concepts for legacy applications in order to become a viable option.

SISO deals with all three aspects, and in the Study Group reports and among the additional SIW papers, candidates of all three categories can be found. To decide which is the most promising solution would be premature, although the author definitely prefers the option of a common infrastructure. However, to reach this long-term goal, working interface solutions will be necessary to proof the feasibility and demonstrate the operational usefulness are necessary, and the work being done in this category may be reused for migration solutions later. The use of C3I components is also just a step to a common infrastructure, as it only makes sense to use C3I components if they are efficient enough to use them in the M&S context, i.e., if it makes sense to reuse them.

To summarize the underlying problem it can be stated, that standards are needed to bridge the gap between legacy systems as well as standards to avoid stovepipe like developed systems in the future. In addition, migration procedures are necessary to transform valuable legacy applications for future use.

While the final report of the "C4I Study Group" (March 1999 – September 2000) [5] framed the problem and identified valuable approaches, the final report of the Study Group on "C4ISR/Simulation Technical Reference Model Study Group" (March 2001 – September 2002) [6] started to focus on standardizable framework concepts. In addition, a C4ISR/Sim Technical Reference Model Sourcebook [7] as well as a User Guide to the C4ISR/Sim Technical Reference Model [8] were initiated to deliver additional guidance for potential users. These two last documents will be presented during the Fall 2003 SIW.

3 THE C4I STUDY GROUP

In order to assess "where we are and where we need to go," SISO charted an M&S-to-C4I Interoperability Study Group to:

- Provide background and current information on C4ISR and simulation interoperability efforts;

- Provide a standards-based assessment of past and current interoperability efforts; and
- Make recommendations on how the SIW C4I Forum should proceed with standards development activities.

The final report of this Study Group [5] discusses “where we have been,” “where are we now,” “where we should go,” and “how do we get there.” While the authors of this report have collated submissions and edited this report, in truth it is the result of more than a dozen direct contributions in the form of draft sections and the indirect contributions of the more than one hundred subscribers to the SG-C4I reflector.

The main reason for setting up a study group was user requirement driven, i.e., derived from necessities to support preparing and conducting future military operations. Simulation interfaces to Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems are essential to support:

- Simulation Based Acquisition (SBA);
- Development of Doctrine, Tactics, Techniques, and Procedures (DTTP);
- “Train as you fight,” in particular Computer Assisted Exercises (CAX);
- Embedded Training (both individual and collective);
- Course of Action Development and Analysis;
- Mission Planning and Rehearsal; and
- Execution Monitoring.

To satisfy the Study Groups goals, this report comprises:

- Background and current information on C4ISR and Simulation Interoperability efforts;
- A standards-based assessment of past and current interoperability efforts; and
- Recommendations on how the Simulation Interoperability Workshop (SIW) C4I Forum should proceed with M&S-to-C4I interoperability related standards development.

3.1 Message oriented Approaches

An overview of previous attempts to couple M&S and C3I systems establishes the basis for the assessment and the recommendations in the final report. As the contributors to the report mainly gained their experience in the United States, the majority of the examples are from U.S. systems. However, some examples from the NATO environment are given as well. The first approaches used C3I messages to couple command and control and simulation systems. Mainly to support CAX, simulation systems were used to create tactically meaningful and adequate text messages, e.g., in ADatP-3, OTH Gold or USMTF format.[1] The link between the Tactical Simulation (TACSIM) to the U.S. Automated Defence Information Network (AUTODIN) message system in support of the Tactical Exploitation of National Capabilities (TENCAP) program in 1980 is an early example of such efforts. Another example given in the report is the link of TACSIM to the Korea Combat Support System (KCSS) and the Korea Air Intelligence System (KAIS) for key intelligence message traffic. KCSS and KAIS were the primary C3I systems that supported the Air Component Command (ACC) of the Korean Combined Forces Command (CFC). During this same event, there was a linkage developed and implemented between the Air Warfare Simulation (AWSIM) and Tactical Receive Equipment (TRE)/Tactical Related Applications (TRAP) systems. From TRAP, the information was fed through a TENCAP project component known as the Air Defence Systems Integrator (ADSI). This allowed enemy aircraft tracking data to be input to the air defence cell at the Control and Report Centre (CRC). In this way, there was established a direct linkage of

[1] ADatP = Allied Data Publication; OTH = Over the Horizon; USMTF = United States Message Text Format.

simulation data to major operations and intelligence centres, including the intelligence I&W centres, Electronic Combat Centre, Control and Report Centre, and Combat Operations.

Of particular interest could be the example of the Warrior Preparation Centre (WPC), a U.S. facility for Command Post Exercise (CPX) support in Germany. In 1994, the WPC built a two-way interface between AWSIM to the Contingency Theatre Automated Planning System (CTAPS). The objective of the effort, known as Project Real Warrior (PRW), was to maintain the existing simulation to C4ISR interfaces, expanded those where possible, and to establish a database link from the CTAPS to AWSIM. The primary motivation behind this effort was the reduction of manpower within the exercise response cells by providing an automated entry of the Air Tasking Order (ATO) into AWSIM. Since the ATO can contain upwards of 2000 missions per day, this offered a significant reduction in manpower requirements. These systems were used for later NATO exercises as well and many lessons learned were derived for NATO efforts in the CAX area.

These early efforts influenced the development of the Modular Reconfigurable C4ISR Interface (MRCI) [10], which attempted to develop a standardized data output stream from a simulation to C3I systems and to incorporate a standardized method for converting C3I system inputs to the simulations. This effort was initially supported by DMSO and later by the Defence Advanced Research Project Agency (DARPA). MRCI was demonstrated during the Synthetic Theatre of War (STOW) 1998 experiment. While many aspects of the MRCI experiment were similar to earlier efforts in C4ISR to simulation interoperability, there were two unique features:

- The attempt to develop a standard interface to the C4ISR environment, in contrast to previous efforts, which in general created unique interfaces to each C4ISR system.
- The attempt to develop and mature a technology for translating command and control directives (or commands) into simulation "orders."

For the second feature, a tool known as the Command and Control to Simulation Interface Language (CCSIL) was developed. However, although MRCI, and in particular CCSIL, were applied several times, they never became widely accepted in any of the two communities.

Additional information on more U.S. efforts, NATO efforts, and national efforts is given in the report [5]. Furthermore, the Long Term Scientific Study on CAX [9] conducted on behalf of the NATO Research and Technology Organization (RTO) Panel on Studies, Analysis and Simulation (SAS) gives some examples as well. In addition to the CPX level efforts described here in some detail, there have been a number of efforts to develop these interfaces at the entity, and even the engineering level, which are not covered in this overview. Furthermore, the use of binary messages, such as Link-16 or the Tactical Digital Information Link (TADIL) family, is an issue not further dealt with in this paper, but you can find paragraphs dealing with examples in the final report of the Study Group.

The main idea of all message driven efforts is the use of the same messages that are used for the information exchange between command and control system. The main advantage of this approach is, that the command and control systems haven't to be changed. The main disadvantage is that the information to be exchanged between C3I and M&S is limited to the message content, and simulation issues normally did not contribute to the definition of these information exchange requirements.

3.2 High Level Architecture driven Approaches

The use of the High Level Architecture (HLA) for M&S systems is a central point in the United States DoD Modelling & Simulation Master Plan [11] as well as in the NATO Modelling & Simulation Master Plan [12]. In late 1994 and early 1995, the Defence Modelling and Simulation Office (DMSO) conducted a baseline assessment of all DoD M&S. From this assessment, DMSO published in the first U.S. DoD

M&S Master Plan in October 1995. This plan established the HLA as a central component of the DoD M&S Technical Framework.

Taking the U.S. DoD M&S Master Plan as one input, in November 1996, NATO began to develop a NATO M&S Master Plan. The Conference of National Armaments Directors (CNAD) established a Steering Group on NATO Simulation Policy and Applications with a mandate to craft an Alliance approach to simulation in order to improve Alliance operations. The resulting NATO M&S Master Plan establishes a co-operative approach for applying advanced simulation techniques to aid in satisfying the needs of the NATO Alliance and its member nations. It is assumed that successful execution of the master plan will promote the aim of Alliance-wide simulation interoperability and reuse, while also providing national and NATO bodies with significant modelling and simulation interest, with the necessary latitude to meet their specific needs. Again, the High Level Architecture plays a central role.

Consequently, C3I to M&S approaches used the concepts introduced by the HLA, in particular the idea to use standardized Reference Federation Object Models (FOM).[2] In the following, some examples are given that were used by the Study Group. All FOMs are included in the library that have been developed by the Study Group and can be downloaded from the SISO website.

The Prototype C4I FOM is the result of a U.S. Army requirement to develop a common environment to facilitate the use of constructive, virtual, and live simulations in the evaluation of C3Isystems in the Research, Development, and Acquisition (RDA), the Advanced Concepts and Requirements (ACR), and the Training, Exercises, and Military Operations (TEMO) domains. To be effective, the simulation environment must be capable of interoperating with real C3Isystems in a manner that is flexible, extensible, and promotes re-use of software components. The prototype C4I FOM is a step toward providing this capability by providing a standardized representation for interoperability that can be applied to a variety of C3Isystems.

The Naval Research Laboratory is developing a C4ISR FOM for DII COE based C4ISR systems under the sponsorship of DMSO and DISA. The C4I Ambassador software provides two-way links between the embedded RTI and the DII COE Services, databases and C4ISR Mission Applications. It interprets the FOM (parses and reformats data as necessary) and manages simulated data distribution within C4ISR. This development builds on the technology contained within the recently released Global Command and Control System (GCCS) Embedded Training Segments for inserting training data into operational GCCS systems.

The Study Report also includes sections on additional FOMs, among others the U.S. Joint Forces Command J6 NETWARS FOM, and shows potential for alignment. The principals, however, are the same among these approaches.

The main idea of these FOM driven approaches is to capture the aligned information exchange requirements using the format of the High Level Architecture Object Model Template. The main advantage of this approach is that HLA compliant systems can easily use this information. The main disadvantage is that the command and control systems' interfaces have to be adapted to the needs of HLA.

3.3 The Vision of the C4I Study Group

It would go beyond the scope of the overview of the final report of the first Study Group to deal with every detail. To be able to cope with the vision, however, it is necessary to know that various architecture concepts were evaluated as well. In particular their contributions to interoperability of C3I and M&S were

[2] It is assumed that the reader is familiar with the High Level Architecture; therefore, the concepts are not introduced in this paper.

an issue. To the evaluated architectural concepts belong the High Level Architecture (HLA), the Joint Technical Architecture (JTA), the U.S. Defence Information System Agency (DISA) defined Common Operational Environment (COE), and the NATO C3 Technical Architecture (NC3TA). Furthermore, various existing federations are described in the final report to complete the state of the art section. Based on the findings, the in the following paragraphs summarized vision was formulated.

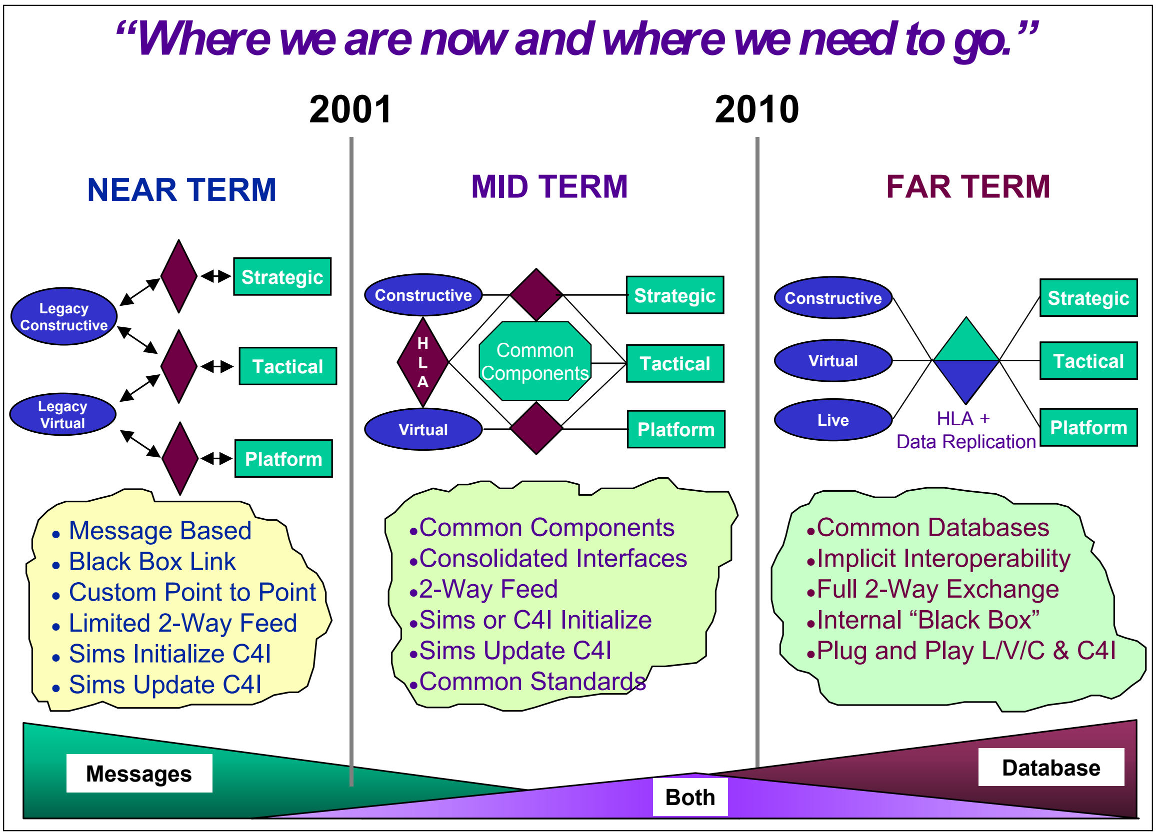

Figure 1: Vision for the Way ahead (C4I Study Group, 2000)

The roadmap for improving the interoperability between simulations and C3Isystems is shown in Figure 1. For the near term, the vision depicts the currently predominant architectures in use for M&S-to-C3I interfaces. Such interfaces are mostly custom "point-to-point" links that are often "black box" in nature. Simulation control is basically one-way, with the simulations initialising the real C4ISR system databases. In the mid term, it is expected to see the HLA linking constructive and virtual simulations on the simulation side and, on the "real" side, the HLA, via common components found in C3I systems (e.g., components of the U.S./NATO Common Operational Environment, such as common message processors) also allowing C3I systems to exchange both data and messages with simulations. Simulation initialisation will be two-way, with real system databases providing information to the simulation side. Ultimately, as shown as "Far Term," a have full two-way linkages via common databases will be achieved, thus achieving a higher measure of interoperability. The vision articulates only a broad vision of where M&S-to-C3I interoperability needs migrate to go over time. The Far Term is not an end state, but is where we could be in 2010 to 2012, if the M&S and C4ISR communities articulate their joint requirements and develop coordinated architectures and standards.

The final report of the Study Group was delivered in September 2000. Many of the mid-term prediction became reality, such is the growing establishment of HLA enriched by completing open standards, although the overall speed of the process has been overestimated, as we are overall moving slower then expected (or maybe hoped for) by the expert group.

4 THE C4ISR/SIMULATION TECHNICAL REFERENCE MODEL STUDY GROUP

The "Report Out of the C4I Study Group" [5] presented during the Fall 2000 SIW called for a standard frame of reference, in the form of a Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR)/SIM Technical Reference Model (TRM), for interoperability between command and control and simulation systems. The C4ISR/Sim TRM defines methods and levels of interoperability of systems or classes of systems. The report also cited the need for the C4ISR/SIM TRM to include a broad data class, Metadata; and requested consideration of how the C4ISR/Sim TRM would relate to other interoperability models in a follow-on study to determine the desirability of integrating the C4ISR/Sim TRM and other interoperability models such as the DoD Level of Information Systems Interoperability (LISI) model, the NATO interoperability model, and other national and international interoperability models. Accordingly, the C4I Study Group (SG) recommended the formation of a follow-on C4ISR/Sim TRM SG to develop a C4ISR/Sim TRM, leveraging existing work; and foster development of that TRM into a formal SISO product. The resulting C4ISR/Sim TRM Study Group worked together for 22 months, including various meetings during the SIWs as well as teleconferences and email exchange. The Study Group consisted of international experts in this domain, however, as before the main interest lay within the United States. The final report [6] was presented during the Fall 2002 SIW and summarizes the efforts of the C4ISR/Sim TRM SG, and provides recommendations for continued development of the TRM.

The C4ISR/Sim TRM SG was formed to create a standard frame of reference for interoperability between C4ISR Systems and M&S systems. The C4ISR/Sim TRM is intended to be used to describe as well as categorize the interoperability of systems or classes of systems. It is a technical model that can be used to measure the level of interoperability of systems or classes of systems. By design, the TRM facilitates analysis of requirements, architecture, design, implementation, and testing of heterogeneous systems. In addition, the TRM is expected to support improved dialogue among users, developers, and technicians in the C4ISR community.

The Study Group realized, that a unified model in form of a single reference model might be difficult to achieve. Therefore, another approach has also been proposed for study by the Study Group: Instead of establishing a new model, existing and established models could be fused as complementing views on the unifying reference architecture. This solution is coherent with solutions proposed in the U.S. DoD C4ISR Architecture Framework [13], the NATO C3 System Architecture Framework [14], the Joint Technical Architecture [15] approach, and furthermore reflects the interoperability solutions being used in the commercial branches of information technology. Although the final report of the second Study Group doesn't make recommendations how the framework should look like (this is done in the follow-on work, see [7]), it identifies the relevant reference architectures in more detail – and adds some new – than this was the case in the initial collection used in the report of the first Study Group.

4.1 Existing C3I to M&S Interoperability Technical Reference Models

The first TRM to be mentioned is the "House Diagram," which has been developed by Michael Hieb and Andreas Tolk to facilitate the discussions within the SIW C4I forum. It was picked up by various authors and proofed to be a valuable although simple way to structure the various interoperability domains. In summary, the "House Diagram" blueprints the complexity of interfacing simulation systems and command and control systems. This holistic view emphasizes the interdependency of five major factors involved in the effort to secure shared solutions for C3I/M&S interoperability: Architectures Alignment, Common

Data/Object Models, Common Standards, Alignment Processes, and Reusable Component Interfaces.

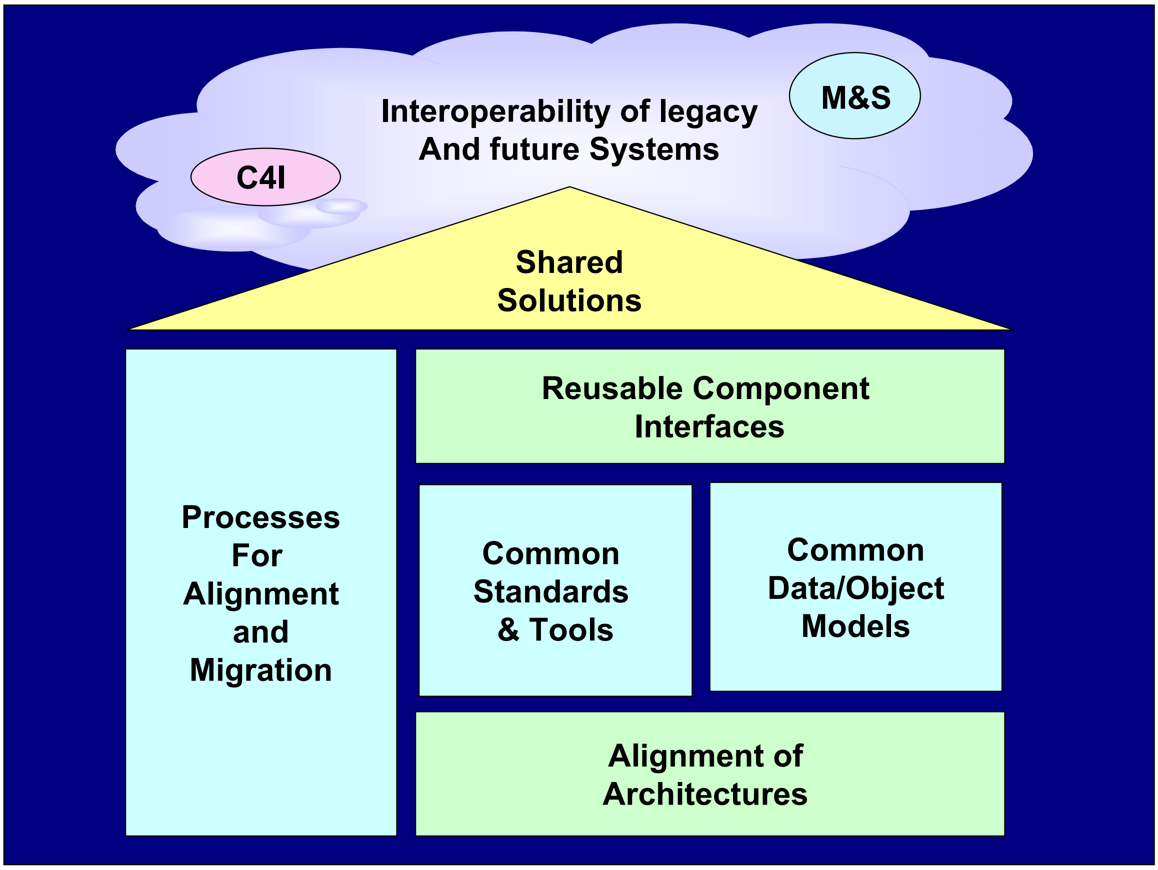

Figure 2: The "House Slide" on Interoperability

Architecture Alignment recognizes the fundamental necessity to align the framework architectures for both M&S and C3I domains. As already pointed out earlier, the U.S. DoD C4ISR community has developed the Defence Information Infrastructure Common Operating Environment (COE). NATO is using the NATO Technical Architecture Model (NC3TA), including the NATO COE. The M&S community has established the HLA. These constructs establish the foundations that set the requirements for fundamental interoperability between components of these two domains. The architecture alignment needs to be able to resolve differences in viewpoints or fundamental representation of the problem space.

Within the M&S domain, the HLA Federation Object Model (FOM) methodology is used to align *Data Models and Object Models* among M&S federates. While this methodology works, it places a heavy burden on developers. When extending beyond the M&S domain into the C3I domain, temporary (situational) alignment presents additional challenges: synchronizing development cycles, aligning domain ontology, and coordinating data standards. These constraints normally resolve into the need for a data translation layer between C3I and simulation domains. However, this gateway strategy can exact a major performance penalty. If systems are aligned to the same or similar object model or data model representations, performance increases as translation penalties and FOM alignment burdens decrease.

Common Standards are most effective when they are part of the system design. Integration of standards begins with the framework architecture for each domain and extends through the support for common objects and data models. To this end, C3I and M&S systems should be designed initially for interoperability.

Reusable Component Interfaces sit on top, and therefore rest upon, the building blocks below. However, when compared to architectures, models, or standards, interfaces have been a hotbed of activity. This apparent paradox stems from our ability to partition the problem space at the interface and thus provide short-term solutions for quick success. However, in general these solutions are too shallow, one has to pay and pay again for these unique interfaces in terms of costs, time, and flexibility. If realignment of the underlying structures eliminates basic incompatibilities between the systems and a wealth of benefits ensues.

Finally, the roof of the house diagram envisions *Shared Solutions* between C3I and Simulations. This aspiration must be supported by all of the underlying blocks. In addition, it requires that the systems align or translate inherent processes. For example, terrain alignment and object placement must be consistent between components in both domains.

The second TRM evaluated in the final report of the C4ISR/Sim TRM Study Group is the C4ISR/Sim Technical Reference Model for Interoperability as introduced by Carr and Hieb in [16]. The C4ISR/SIM Interoperability TRM identifies data types exchanged between C3Iand M&S systems. Systems engineers identify data requirements and code interfaces to handle information exchanges between C3I and M&S systems. Generalizing these efforts, one can document and classify information that an interface must handle. The C4ISR/Sim Technical Reference Model for Interoperability builds the basis for the follow-on efforts dealt with in the next section.[3] Therefore, we will not discuss this TRM at this point.

The third TRM has been introduced by Ressler, Hieb, and Sudnikovich [17]. They describe a reference model focused on the information exchange activities between C4ISR and M&S components. They suggest a conceptual reference model based on the decomposition of processes for exchanging data between C4ISR and M&S systems. Their Information Exchange Activity Model forms a central component of a generalized C4ISR/Sim conceptual reference model. This Information Exchange Activity Model captures activities essential to establishing interoperability between domains.

To cope with the aspects of architecture alignment as proposed in the "House Slide," Furness, Carr, and Hieb introduced the fourth TRM, the General Unified Model (GUM) for M&S to C3I interoperability [18]. This high level model divides both architectures of the M&S and C3I families into four categories providing the ability to accommodate functions present in any representative implementation. A reasonable set of the common functions of both C4ISR systems and M&S systems provide the starting point for the GUM. The resulting candidate set of common functions comprises User Interfaces, Management and Execution, Data, and Algorithms. This list is neither complete nor exclusive, but helps to structure the architectural domains that have to be interoperable for a given purpose.

A lot of work being presented within recent SIW are relevant to this effort as well and has to be taken into account although not directly connected to a reference model. The topics of meta data, meta modelling and the problem of data alignment have to be stressed in this context. The new role of data engineering emerged from respective findings. Within actual solutions of C4ISR and M&S system coupling, the system designer tasked with the integration has to know *what* data is located *where*, the *meaning* of data and its *context*, and into what *format* the data have to be transformed to be used in respective distributed applications within the overall system. *Data Engineering* is coordination the efforts of the sub-tasks of data administration, data management, data alignment, and data transformation. The first three can be standardized and used in a general manner. Only the task of transforming the data really is system dependent, and it has been shown that even for this task a general solution exists.

[3] Furthermore, Carr presents during this NATO Symposium his recent findings and recommendations in Paper No. 18 within this proceedings.

- *Data Administration* is the process of managing the information exchange needs that exist within a group of systems, including the documentation of the source, the format, context of validity, and fidelity and credibility of the data. Data Administration therefore is part of the overall information management process.

- *Data Management* is planning, organizing and managing of data by defining and using rules, methods, tools and respective resources to identify, clarify, define and standardize the meaning of data as of their relations.

- *Data Alignment* ensures that the data to be exchanged exist in the participating systems as an information entity or that the necessary information can be derived from the data available, e.g., using the means of aggregation or disaggregation.

- *Data Transformation* is the technical process – often implemented by respective algorithms within the gateways and interfaces – of aggregation and/or disaggregation of the information entities of the embedding systems to match the information exchange requirements including the adjustment of the data formats as needed.

Most actual works are focusing on data transformation, i.e., the programming or maintenance of interfaces. However, if such efforts are not accompanied by an alignment of the respective management processes for data administration, management, and alignment, the result is in the best case a temporary valid solution that is effective until the next update of one of the participating systems. Consequently, the managing processes of the participating systems must at least be harmonized. In the ideal case, the program managers will even use the same methods and supporting tools to do so under a common, overarching approach as already proposed by the House Slide in an earlier section.

4.2 Relevant Reference Models from C3I and Commercial Information Technology

In addition to the existing C3I to M&S interoperability TRM, relevant reference models not only from the C3I community, but also from the commercial IT world were evaluated. For the complete evaluation, the interested reader is referred to the final report. In this overview, we will just mention the models and deal with the two that played a central role in the Study Group, namely the Level of Information Systems Interoperability (LISI) [19] and the NC3TA Model of Interoperability (NMI) [3].

The LISI model provides a reasonable framework to scope the needed level of connectivity in the domain of technical interoperability. LISI is established by the U.S. DoD C4SIR Framework Architecture [13]. LISI identifies four domains, namely Procedures and Policy, Applications, Infrastructure, and Data (PAID). Every one of the PAID domain impacts on information exchange, in other words, a level of interoperability exists within each of the PAID domains. The resulting technical interoperability is measured in five categories:

- Level 0: Isolated (Manual) – Non-connected, use of manual gateways (diskettes, etc.)

- Level 1: Connected (Peer-to-Peer) – Electronic connection; Separate data and applications

- Level 2: Functional (Distributed) – Minimal common Functions; Separate data and applications

- Level 3: Domain (Integrated) – Shared data; “Separate” applications

- Level 4: Enterprise (Universal) – Interactive manipulation; Shared Data and applications

Level 4 is the highest level of technical interoperability, i.e., data is electronically delivered to the

Warfighter regardless what access method he uses (from handheld to C3I workstations) and from where he uses this device. He can just plug into the infosphere and can use all applications, wherever he is and wherever the applications are.

LEVEL (Environment)			Interoperability Attributes: Procedures	Applications	Infrastructure	Data
Enterprise Level (Universal)	4	c	Multi-National Enterprises	Interactive (cross applications)	Multi-Dimensional Topologies	Cross-Enterprise Models
		b	Federal Enterprise			
		a	DoD Enterprise	Full Object Cut & Paste		Enterprise Model
Domain Level (Integrated)	3	c	Domain Service/Agency Doctrine, Procedures, Training, etc.	Shared Data (Situation Displays Direct DB Exchanges)	WAN	DBMS
		b		Group Collaboration (White Boards, VTC)		Domain Models
		a		Full Text Cut and Paste		
Functional Level (Distributed)	2	c	Common Operating Environment (DII-COE Level 5) Compliance	Web Browser	LAN	Program Models and Advanced Data Formats
		b		Basic Operations (Documents, Maps, Briefings, Pictures Spreadsheets, Data)		
		a	Program Standard Procedures, Training, etc.	Advanced Messaging (Parsers, E-Mail+)	Network	
Connected Level (Peer-to-Peer)	1	d	Standards Compliant (JTA, IEEE)	Basic Messaging (Plain Text, E-mail w/o attachments)	Two Way	Basic Data Formats
		c		Data File Transfer		
		b	Security Profile	Simple Interaction Text Chatter, Voice, Fax, Remote Access, Telemetry)		
		a			One Way	
Isolated Level (Manual)	0	d	Media Exchange Procedures	N/A	Removable Media	Media Formats
		c	Manual Access Controls — NATO Level 3		Manual Re-entry	Private Data
		b	Manual Access Controls — NATO Level 2			
		a	Manual Access Controls — NATO Level 1			
		o	No Known Interoperability			

Figure 3: The LISI Model

NATO is using a very similar model to LISI. It is comprised in the NATO C3 Technical Architecture (NC3TA) [3]. The NC3TA describes the IT architecture to be used as a basis for interoperable NATO systems. It addresses architectural descriptions, reference models, and Off-The-Shelf (OTS)-technologies. Furthermore, the NC3TA integrates technical aspects of specific architectures or frameworks such as the NATO Information Security Framework. The NC3TA consists of five volumes dealing with Management, Architectural Models and Description, Base Standards and Profiles, NC3 Common Standards Profiles (CSP), and the NC3 Common Operating Environment (COE). The NC3TA contains five technical reference models of interest to our review of C4ISR/M&S interoperability:

- The *NC3TA Technical Reference Model* (NTRM) provides the conceptual framework and common vocabulary for addressing interoperability and compatibility among NATO information systems. It sets a foundation for all NC3 technical architectures.

- The *NATO Common Operating Environment* (NCOE) Component Model (NCM) instantiates the NTRM and models the NCOE architecture. In turn, the NCOE aspires to define a plug and play client/server environment [Volume 5] to increase interoperability, reusability, portability, and operational capability while reducing development time, technical obsolescence, training requirements, and life cycle cost.

- The *NATO-Common-Funded (NCF) Reference Models for Functional Configurations* (NFC) refines the NCM. This set of reference models provides functional configurations as building blocks for developing the functional architecture of NCF systems.

- The *NATO Reference Model for Open Systems Information Interchange* (NOSI) focuses on communications issues not covered by previous models.

- The *NC3TA Reference Model for Interoperability* (NMI) models technical interoperability by leveraging the concept of degrees of interoperability. Categories of elementary services form a descriptive basis for functional interoperability profiles.

The NC3TA reference model for interoperability (NMI) establishes interoperability degrees and sub-degrees. Interoperability degrees define a *maturity model* that captures interoperability sophistication. Interoperability sub-degrees describe a *capability model* that reflects available functionality. These degrees highlight the value of structuring and automating exchange and interpretation of data to enhance operational effectiveness. The NMI provides definitions for interoperability degrees and sub-degrees and presents interoperability profiles. The NMI classifies interoperability at four levels.

- Degree 1: Unstructured Data Exchange
  This level involves the exchange of human-interpretable, unstructured data such as the free text found in operational estimates, analysis, and papers. Sub-degrees are Network Connectivity, Basic Document Exchange, and Basic Informal Message Exchange.

- Degree 2: Structured Data Exchange
  This level involves the exchange of human-interpretable structured data intended for manual and/or automated handling, but requires manual compilation, receipt, and/or message dispatch. Sub-degrees are Enhanced Informal Message Exchange, Enhanced Document Exchange, Network Management, Map Overlays/Graphics Exchange, Directory Services, Web Access, Multi-Point Applications, and Data Object Exchange.

- Degree 3: Seamless Sharing of Data
  This level involves automated data sharing within systems based on a common exchange model. Sub-degrees are Formal Message Exchange, Common Data Exchange, System Management, Secure Systems Management, Security Management, and Real–time Data Exchange.

- Degree 4: Seamless Sharing of Information
  An extension of degree 3, this level establishes universal interpretation of information through cooperative data processing. Sub-degrees are Common Information Exchange, and Distributed Applications.

Unconnected systems, which would represent the interoperability level of degree zero, are not mentioned in the NATO C3 Technical Architecture. The Seamless Sharing of Information (degree 3) equals the Universal Interoperability Level (level 4) of Enterprise Solutions as envisioned in LISI.

The final report of the C4ISR/Sim TRM Study Group furthermore deals the other NC3TA technical reference models and their applicability as well. In the context of this paper it may be worth mentioning that the IEEE POSIX Open System Environment (OSE) Reference Model [20] is part of these NATO TRM. The POSIX model is the basis for other TRM as well, e.g., the U.S. DoD and U.S. Federal Technical Reference Models.

The final report of the C4ISR/Sim TRM Study Group ends with the recommendation to enhance the C4ISR/Sim Technical Reference Model as proposed in [16]. In addition, a C4ISR/Sim TRM Sourcebook and a user guide are recommended. The SISO committees accepted all three recommendations. Therefore, a third Study Group was launched in Fall 2002.

5 THE C4ISR/SIM TECHNICAL REFERENCE MODEL SOURCEBOOK AND THE USER GUIDE TO THE C4ISR/SIM TECHNICAL REFERENCE MODEL

While the previous two sections deal with conducted Study Groups, this section is dealing with the ongoing efforts of the third Study Group of SISO dealing with the issues of C3I to M&S interoperability. The results will be presented during the SIW Fall 2003. However, as the author is member of the editor and contributor committee for the reports of this third Study Group, preliminary results of the respective drafts could be comprised in this paper already. However, it is strongly recommended to look at the sourcebook [7] and the user guide [8] as soon as they are published.

Two of the efforts described in the Sourcebook [7] will be described in this overview. The first is the first draft of the C4ISR/Sim TRM Framework; the second is the C4ISR/Sim TRM in the actual state as derived starting with the model as introduced by Carr and Hieb in [16].

It already has been pointed out that the technical solutions being already available are doomed to failure if not accompanied by respective organizational and procedural alignments. New evolving standards within the IT world – such as the Extensible Mark-up Language (XML) – are often perceived to deliver long searched solutions, but in general they only affect one factor of the "house slide" as depicted in the last section. Without the emphasized holistic view the vision of one common command and control systems based on heterogeneous information technology implementing the required functionality of command and control as well as Operations Research – including modelling and simulation – will remain a pure wish. In this sense, the various TRM presented in the second report as well as in the last section of this paper are dealing only with special aspects of the challenge to reach interoperable and shared solutions. In general, all these views and models are needed to support "the big picture."

The C4ISR/Sim TRM Study Group first dealt with this issue in Spring 2002 and recommended as a long-term goal to establish a framework comprising various complementary C4ISR/SIM TRM views, following the example of the U.S. DoD C4ISR Architecture Framework [13] and/or the NATO C3 System Architecture Framework [14], both of which using operational, system, and technical views to describe the command and control architecture in total. Figure 4 shows the proposed structure without claiming completeness. The various candidates are those mentioned in the TRM sections of the previous two reports.

The four recommended views are the *Functions and Data View*, which focuses on the data exchanged and functions provided via the interfaces of the M&S and C3I systems, the *Software Component View*, which deals with the components to be addresses or reused within the participating M&S and C3I systems, the IT Systems View, which deals with the information technology aspects not being special to M&S or C3I systems but still influencing their way how to interoperate, and finally the *Level of Interoperability View*, introducing the necessary measures of merits and metrics to measure interoperability as well as to define the level of necessary interoperability to reach a requirement driven solution.

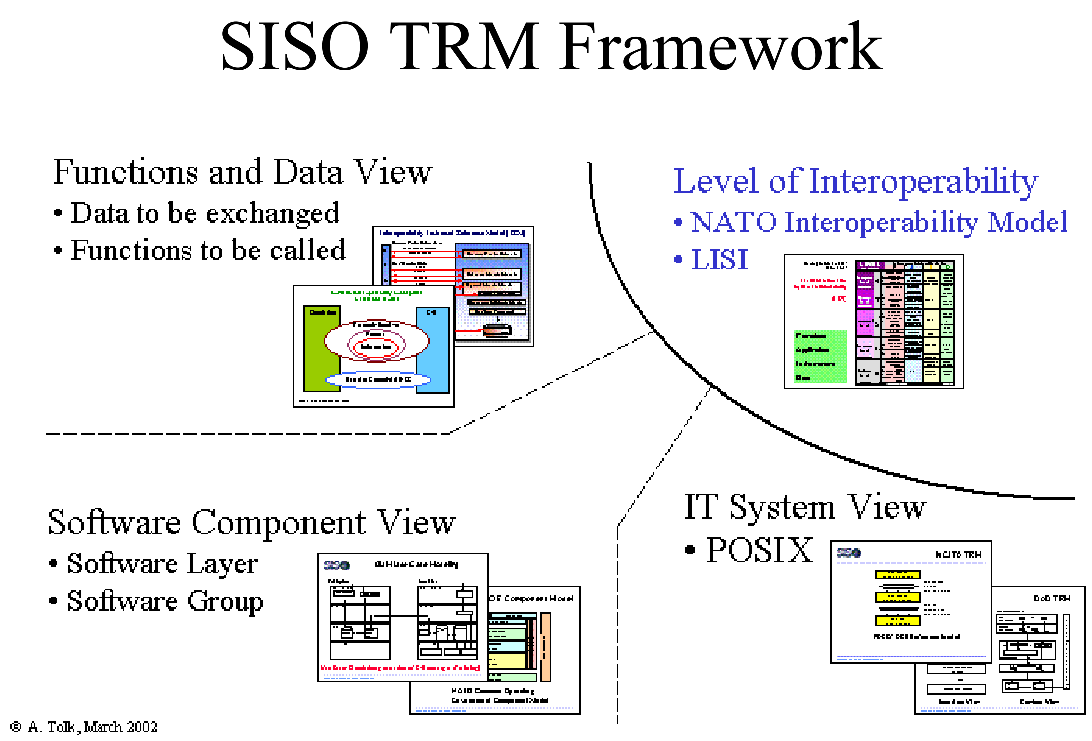

Figure 4: A Possible C4ISR/Sim TRM Framework

All three Study Groups of SISO coping with M&S to C3I Interoperability used the model introduced by Carr and Hieb in [16] and improved it gradually. Although the model is mainly focussing on the standardization of interfaces, in particular the data to be exchanged M&S and C3I systems, and furthermore has been applied mainly in the domain of CAX[4], it can be seen as one of the most matured and applied models evaluated by SISO in this context. The presented version is not the end state. It is much more likely that it will be further developed and improved. In particular F. Carr has to be mentioned in this context, who is responsible for the lion share of the improvements being done in the course of the three Study Groups (see also footnote on page 1-11).

The C4ISR/Sim TRM depicts the types of data that must be exchanged between C3I and simulation systems in order to conduct effective events. As used here, "effective" means satisfying the user requirements for an event (e.g. fair fight, level playing field, real-time, data capture and replay). "Event"

[4] When using M&S system to support military operations as decision support systems, a whole new set of requirements must be fulfilled, see, among others, Andreas Tolk and Dietmar Kunde: "Decision Support Systems in the Military Environment", Chapter 6 in *"Innovations in Decision Support Systems", Tonfoni G. and Jain L. (Eds.), International Series on Advanced Intelligence, Advanced Knowledge International, ISBN 0-86803-980-2, Magill, Adelaide, Australia, 2003, pp. 175-210*

means any interaction between C3I and simulation systems, irrespective of the purpose (e.g. training, testing, planning, analysis). The C4ISR/Sim TRM describes four broad categories of information exchanged between C3I and M&S systems, which are Simulation Service Interactions, Non-Persistent Data, Persistent Data, and C4ISR System Service Interactions. It also defines subcategories. For the exact definitions and examples, please refer to [7].

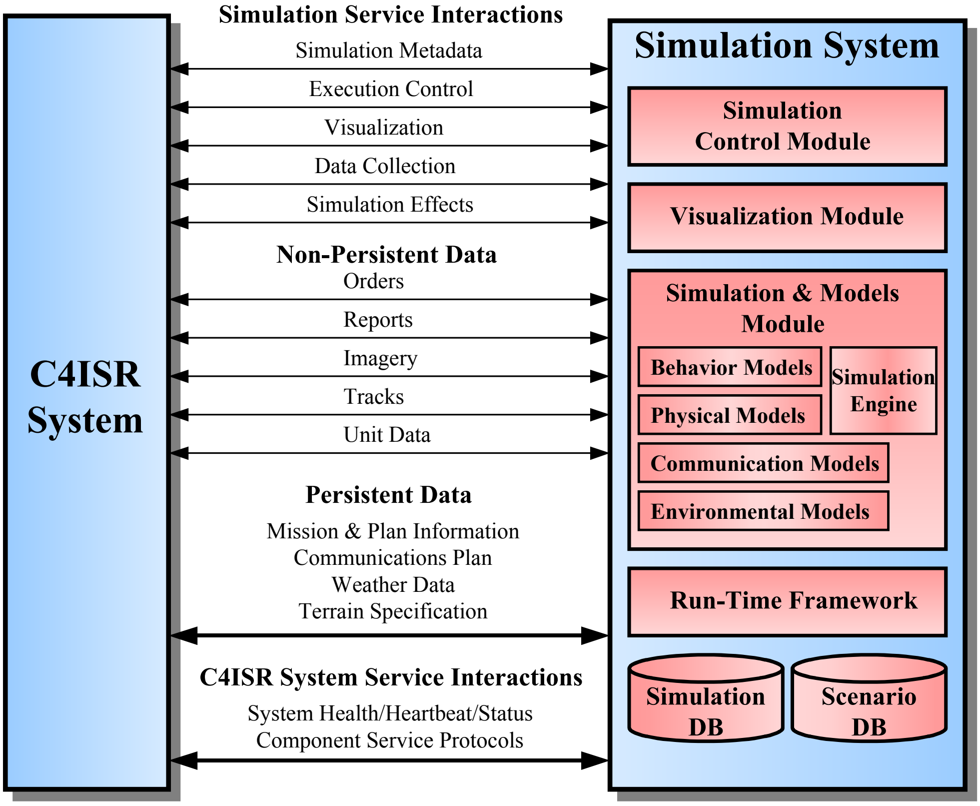

Figure 5: The C4ISR/Sim Technical Reference Model

Simulation Service Interactions are information exchanges that primarily support the simulation systems requirements. This category includes information about the simulation, and information necessary to control or coordinate its execution with C3I resident activities. Five subcategories are Simulation Metadata, Execution Control, Visualization, Data Collection, and Simulation Effects.

Non-Persistent Data is data that will likely change during the course of an event. The interface mechanism selected for Non-Persistent Data must support dynamic updates. Periodic and/or event driven updates may be required. For example, a simulated entities' position may be sent to a C3I system at 30 Hertz, or only when triggered by a dead reckoning algorithm. Even though the position of an entity may not change during a particular event, it is still viewed as Non-Persistent Data because it is subject to change. Non-Persistent Data refers to the class of information that is transient, corresponding to interactions between entities or objects in the simulation or C3I database, or updates to an entity's state. Subcategories are Orders, Reports, Imagery, Tracks, and Unit Data.

Persistent Data is data that is reasonably static and generally set during system initialisation. The ability to provide direct transfer of C3I data from the suggested sources to simulation equivalents for scenario initialisation purposes can provide substantial cost savings, set-up time reductions, and increased flexibility for simulation use. So far identified subcategories are Mission & Plan Information, Communication Plans, Weather Data, and Terrain Specifications.

C4ISR System Service Interactions are exchanges of information that may be mandated by use of particular C3I components, or merely by virtue of being connected to a C3I system. They may not contain data that is exchanged between the two domains, but may be required in order to connect to the C3I system, sustain the connection, or to use a particular C3I component. So far identified subcategories are System Reports on Health/Heartbeat/Status needed by the C3I system and Component Service Protocols required by participating C3I systems.

The following alternative view has been developed by the author based on the C4ISR/TRM. It is primarily intended to extend the view from CAX to Support to Operations and to include the C3I relevant components on the level of the GUM. This is a high level view on M&S to C3I interoperability and is intended to extend the C4ISR/Sim TRM into a more general direction (by combining the Functions and Data View and the Software Components View as introduced in Figure 4 into one model). It must be pointed out that this view is actually not adopted by SISO but the personal view of the author.

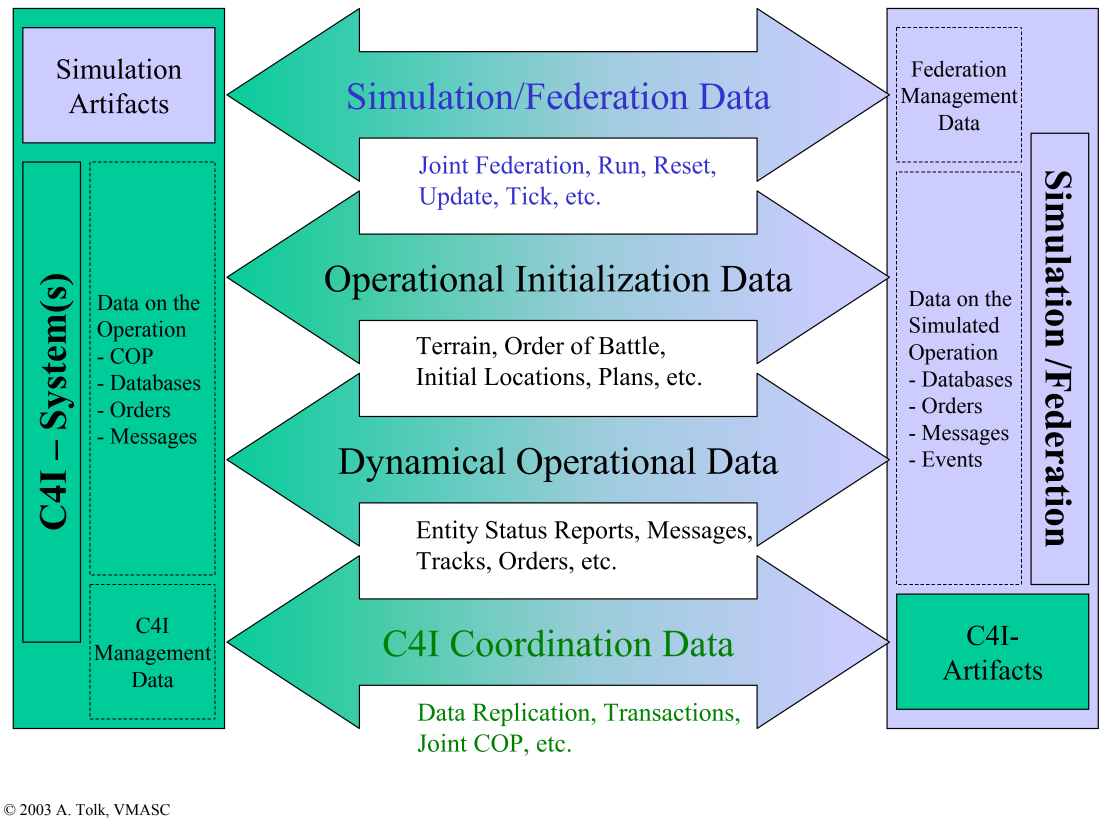

Figure 6: High Level View on M&S to C3I Interoperability

In addition to the sourcebook, a user guide for the C4ISR/Sim TRM, as developed by the Study Groups, will be published [8]. The five primary guiding principles for developing the C4ISR/Sim TRM were, that the TRM must be comprehensive, easy to interpret, traceable, usable, and independent. The user guide will in particular help to make the model easier to interpret and more usable.

6 SUMMARY

The three Study Groups conducted under the aegis of the SIW C4I forum of SISO within the recent years help tremendously to identify burning issues within the domain of M&S to C3I Interoperability. All reports and interim products are available to the public via the SISO library [21]. These documents are valuable sources for everyone being interested in this domain of increasing importance.

The author is convinced that C3I and M&S components will continue to merge in the future. The recent developments within the C3I community improved the command and control capability and quality in on order of magnitude by replacing the messages with a Common Operational Picture (COP), which proofs the saying that "a picture says more than 1,000 words." The next order of magnitude improvement will be the introduction of M&S components to communicate the commanders intend in a much more efficient way, which could be stated as "a simulation execution says more than 1,000 pictures." The C3I community is still driven mainly by intelligence, surveillance, and reconnaissance resources, driven by the requirement to create a consistent picture out of various incomplete, unsharp, uncertain, inconsistent, and contradictive pieces of information. The user requirement for more agile support leads to dynamical structures as being supported by the M&S communities since years. Both communities, M&S and C3I, have essential contributions to the heterogeneous information infrastructure to support the Warfighter in his future operations.

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The website of the Simulation Interoperability Standards Organization is the most valuable source of information regarding the topic of this paper. Most of the information is available to the public, however, some areas require a password, which automatically comes with the membership, and some very limited areas are reserved for administration business of special committees. For more information, please refer to http://www.sisostds.org

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ACKNOWLEDGEMENT

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DISCLAIMER

This paper reflects the personal opinion and interpretation of the author regarding the results of the Study Groups. It neither reflects the official SISO policy nor any interpretation of organizational, international, or national institutions or organizations the author is affiliated with.

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A Multi-National, Distributed Testbed for Extended Air Defence BMC3I:

Past Experiences & Vision for the Future

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A MULTI-NATIONAL, DISTRIBUTED TESTBED FOR EXTENDED AIR DEFENCE BMC3I, PAST EXPERIENCES & VISION FOR THE FUTURE

The development and testing of the BMC3I for NATO's extended air defence mission has many challenges. The BMC3I element is responsible for the coordination and integration of the other three primary EAD functional areas: Active Defence, Passive Defence, and Conventional Counterforce and can involve weapon and sensor systems widely distributed over land, sea, air, and even space. These systems may be operated by individual nations or integrated into NATO's command and control structure directly. In addition, the missile defence aspect of extended air defence is relatively new to military operations, with defensive systems capable of negating ballistic missiles being deployed only within the last 10 to 15 years. NATO recognises the need for a more integrated approach to countering the emerging ballistic missile threat as is evidenced by the recently sponsored NATO Active Layered Theatre Ballistic Missile Defence (TBMD) Feasibility Study.

This paper summarizes NC3A's use of modelling and simulation in support of NATO's EAD mission, specifically in the area of C2 interoperability at the technical, systems, and operational levels. It provides a summary of lessons learned from Cannon Cloud '02 and other similar NATO exercises. It gives an overview of some on-going activities that are aimed at developing a strategy for a more cohesive, coordinated approach to the employment of M&S in support of EAD C2 within the NATO community, and some insights into what that future environment might look like.

1.0 INTRODUCTION

1.1 NATO C3 Agency

The NATO C3 Agency (NC3A) was established on 1 July 1996 to provide consultation and scientific support to NATO and is overseen by the NATO C3 Organization (NC3O). Formation of the Agency was achieved by the amalgamation of the former SHAPE Technical Centre (STC) and the NATO Communications and Information Systems Agency (NACISA). The NC3A is located in two facilities: one in The Hague, Netherlands and one in Brussels, Belgium. The NC3A operates under the policy direction of the NATO C3 Board.

The NC3A has two fundamental missions as defined in the charter of the NC3O. The first is to develop and implement, in a timely manner, cost-effective communications and information system capabilities to support NATO's functions pertaining to both Political Consultation and Military Command and Control. The second mission is to provide unbiased scientific advice and assistance to NATO's military and political authorities.

1.2 Missile Defence Branch

The work discussed in this paper was performed by the NC3A Missile Defence (MD) Branch, which performs a lead role in several important efforts supporting NATO's missile defence mission area. Most notable are the Active Layered TBMD Feasibility Study, the Missile Defence Feasibility Study, and the NATO/Russia TMD Interoperability Study. In addition to these, the NC3A Scientific Programme of Work (SPOW), sponsored by NATOs Bi-Strategic Commanders, funds the development of the PLATO and LSID operational prototypes as well as the NC3A portion of the MDA/SHAPE Bi-Lateral BMC3 Study. PLATO (Planning Tool) is NC3A's operational prototype for exploring missile defence planning and tasking requirements and functionality. LSID (Link16 SAMC2 Interoperability Demonstrator) is NC3A's operational prototype for exploring the BMC3I requirements associated with real-time control and coordination of ballistic missile engagements. These activities are all aimed at capturing requirements for NATO's missile defence mission area with the SPOW activities particularly focused on NATO's missile defence BMC3I interoperability issues, and exploring synergies between functional components of MD (ActD, PD and CCF).

Missile defence in NATO is a multi-dimensional operational domain. It addresses potential threat systems of all types, various levels of the NATO command structure, a diverse set of interface exchange requirements, and three main functional areas for negating the missile threat. NATO's emerging BMC3 systems, ACCS & the Bi-SC AIS, will have to efficiently address all of these dimensions.

To adequately capture the requirements associated with these dimensions, the Missile Defence Branch uses a cyclical process utilising a combination of modelling, simulation, and operational prototypes. The requirements are initially generated based upon the results coming out of studies and analysis activities. The requirements are then implemented in prototype software where they can be explored for technical feasibility in detail. The emerging requirements (as implemented in the prototype software) are then put in front of operators in realistic experiments and exercises to evaluate them with respect to their operational utility and usefulness. The process repeats with more and more insight and detail being developed after the completion of each phase. With this approach, BMC3I requirements can be generated quite rapidly even in a complex mission area like missile defence. They can then be included in the development programmes for NATO BMC3I systems (e.g., future enhancements to ACCS or the Bi-SC AIS.)

1.2 Interoperability at all levels

Most NATO BMC3I systems share a common, fundamental concern: interoperability. If the BMC3I system does nothing else, it is usually required to make sure that its systems work together. In NATO missile defence, the BMC3I element is responsible for the coordination and integration of weapon and sensor systems developed by different nations and widely distributed over land, sea, air, and even space.

Interoperability has to be addressed at several levels. First of all is the technical level: systems need to be connected to each other properly before they can start communicating. Then there is the system level of interoperability: systems need to communicate using a common protocol and message standard. And finally there is the operational level of interoperability: each system needs to fully understand the contents of the other's messages and know how that data relates to its own information.

One problem we tend to run into in missile defence BMC3I analyses is that we focus so intently on the interoperability issues associated with the real-world BMC3I systems that we forget to properly deal with the interoperability issues associated with the models and simulations we use in evaluating them. We end up "solving" our M&S interoperability problems over and over again, for each experiment we run, and for each exercise we participate in. Our lessons learned are usually lessons re-learned, and the solutions tend to be applicable only for a given set of models and exercise objectives.

2.0 CANNON CLOUD 2002

We will now describe the 2002 Cannon Cloud exercise, as a case study, to illustrate how the MD branch supports NATO exercises and the issues that are typically encountered in such activities.

2.1 Exercise overview

Cannon Cloud 2002 (CC02) was the second largest exercise on the NATO calendar for that year. It was a large, multi-corps, multi-CAOC, computer aided exercise (CAX) conducted at USAF Europe (USAFE) Warrior Preparation Centre (WPC) in Einsiedlerhof, Germany, and a number of other locations. The primary emphasis of CC02 was to support higher echelon operational training for coalition forces in a large scale, high intensity conflict using the Joint Theatre Level Simulation (JTLS), an aggregate simulation that has served as the SHAPE-approved CAX simulation since 1995. Missile defence was only one part of the overall exercise objectives.

The role of the MD Branch at the CC02 exercise was to provide the hardware, software and communications capability required to provide detailed simulation of TMD activity of suitable fidelity such that the training objectives of the Joint TMD Cell (JTMDC) could be achieved.

The exercise scenario for CC02 utilized actual Northern European terrain with fictitious national boundaries. The Tactical Ballistic Missile (TBM) threats were operated by the coalition of Oliveland and Orania against the Southern region of Montrena (figure 1). The mission of NATO missile defence in this exercise was to protect NATO forces in Montrena from TBM attack through Active Defence (ActD) and Conventional Counter Force Operations (CCFO) against the threat coalition to ensure that threat TBM infrastructure and support systems could be destroyed prior to TBM launch. All functional areas of TMD were to be fully integrated, first of all with each other, but also into the overall exercise.

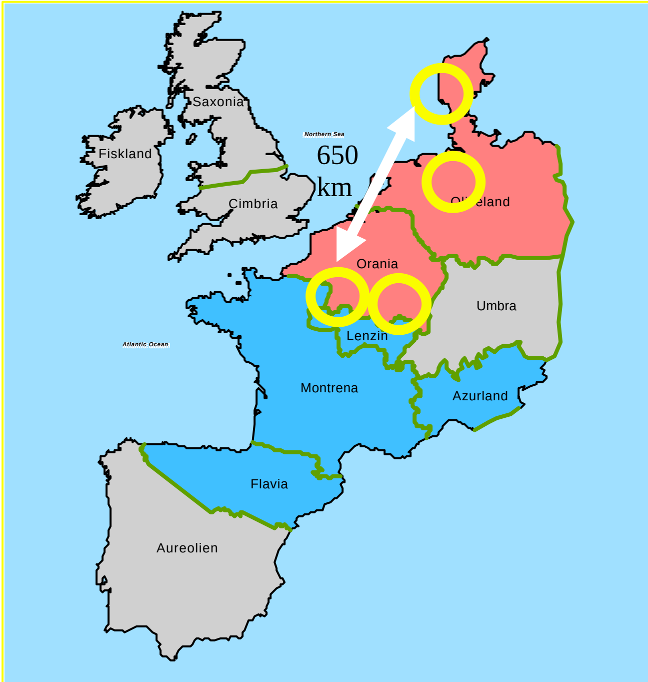

Figure 1: Cannon Cloud 2002 country book

2.2 NATO TMD Doctrine

CC02 exercised all four functional areas of NATO TMD doctrine. Conventional Counterforce Operations: to prevent an aggressor from launching ballistic or other types of missiles by attacking identified launch areas and associated sites. Active Defence: to engage theatre ballistic missiles in-flight. Passive Defence: to mitigate the effects of an attack via camouflage, hardening, dispersal, deception, and by providing early warning. BMC3I: to integrate and coordinate the activities of the other three functional areas in order to efficiently and effectively negate the ballistic missile threat.

During CC02, Conventional Counterforce Operations were supported by the CAESAR simulations for Alliance Ground Surveillance platforms, Active Defence was simulated by EADSIM, and Passive Defence was provided using the operational NATO Shared Early Warning (SEW) system. The JTMDC acted as the hub of the Battle Management/Command, Control, Communications, Computers and Intelligence (BMC3I) capabilities required to coordinate Conventional Counterforce Operations and Passive Defence.

2.3 The aggregation problem

One of the fundamental challenges encountered in supporting CC02 with M&S was the issue of dissimilar levels of unit aggregation between models. JTLS, the core simulation for the exercise, usually aggregates units to the brigade level or larger. Mission specific simulations like OneSAF and EADSIM usually represent units at the entity level in order to accurately capture the detailed effects of signature and kinematics. The challenge then is to find a way for these dissimilar models to operate together.

Figure 2 captures the nature of the multi-resolution modelling problem encountered during CC02. In the middle is a close-up of the hexagon system used by the exercise planners to represent the battle space. Each hex is 7 kilometres across.

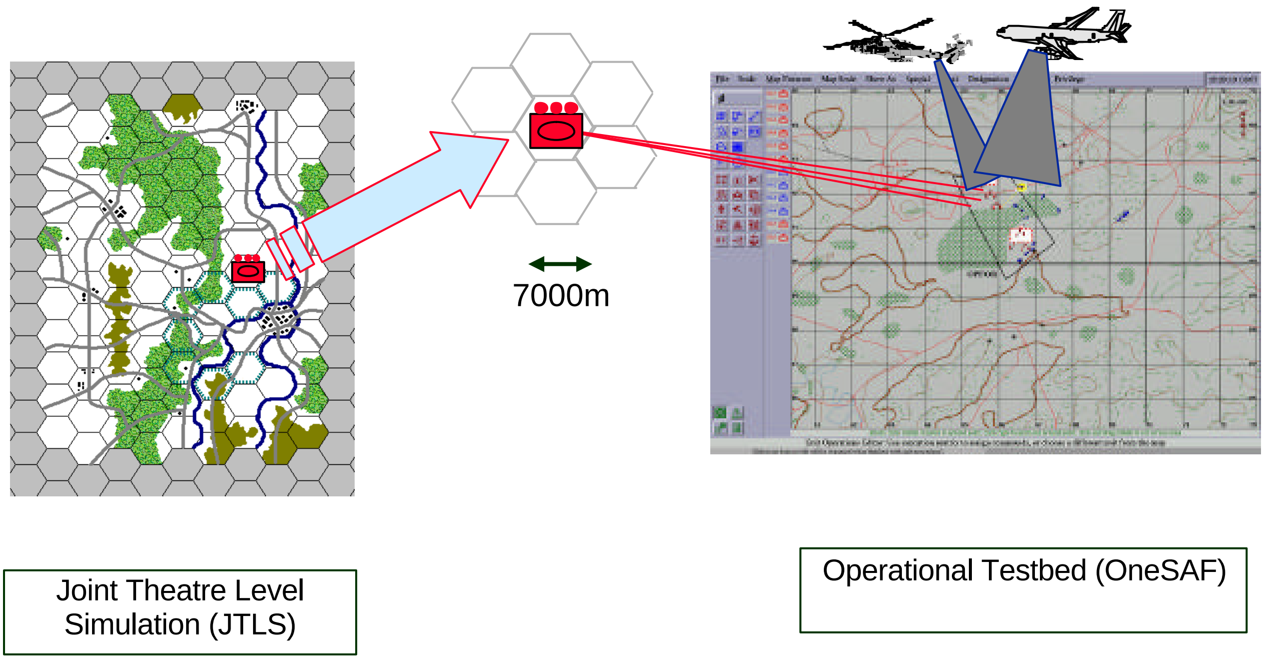

Figure 2: Cannon Cloud 2002 aggregation problem

On the right is a representation of an entity-level simulation used by the CAESAR sensor simulations for Conventional Counterforce Operations. Individual buildings, trees, 100-meter resolution terrain data and roads are all represented in the AGS simulation world.

The errors that arise when combining such simulations can be generalised as:

- Time synchronisation, especially when considering moving targets,
- Location errors are clear when you consider that JTLS generalises features across 7km,
- Velocity, road registration and features are also of concern.

The challenge was to develop an architecture to address these issues.

Figure 3 shows the architecture that was designed to support the TMD operations and to address the issues mentioned above. The architecture minimises the effects of concurrently running dissimilar simulations.

JTLS, again, is the primary simulation. TBM units operated on pre-planned schedules represented by scripts in ITEST and in JTLS. JTLS issues the TBM fire command to EADSIM, which then flies the ballistic missile and conducts the intercept using Dutch and German Patriot units and the Dutch Navy Frigate. When the EADSIM launch occurs, the HLA listener relays the launch information to the SEW Alerter, which injects the launch warning information into the NATO WAN. On the AGS side, the sensors detect the moving entities of ITEST and feed exploitation systems using the common data format (NATO EX). This allows the sharing of national sensor system data.

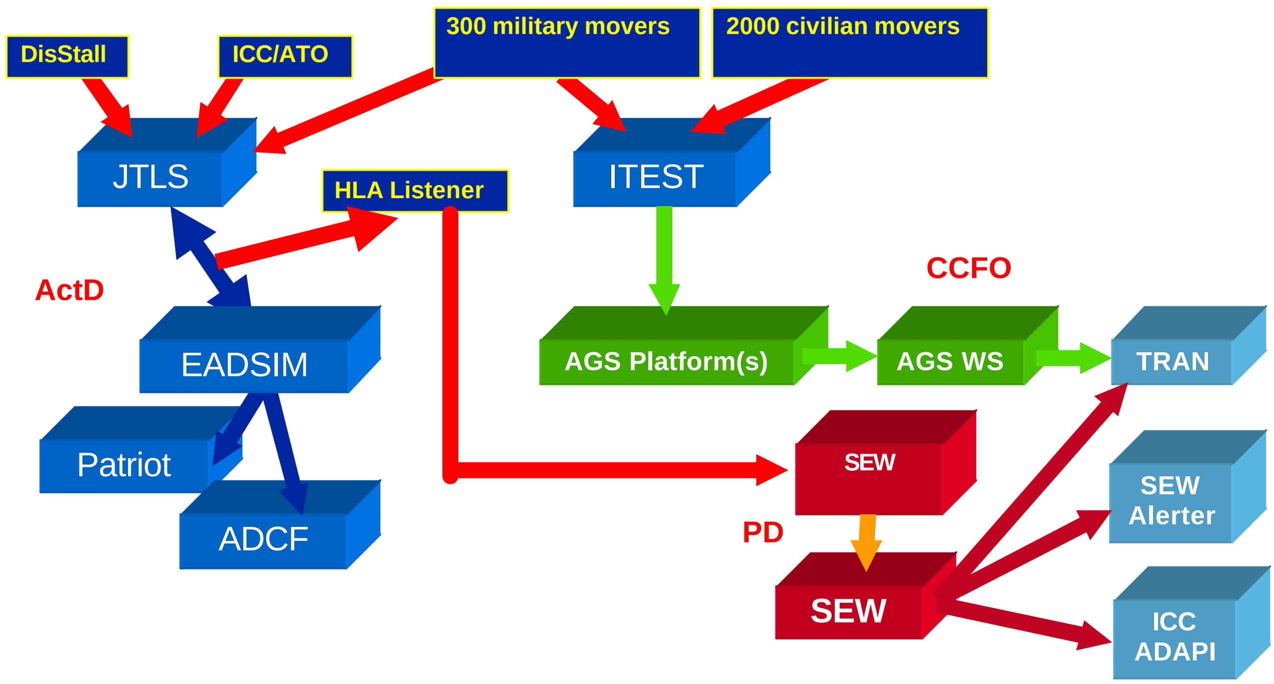

Figure 3: Cannon Cloud 2002 TMD simulation architecture

This architecture solution worked and TMD objectives of the exercise were achieved. However, the use of multiple, simultaneously running scripts (one for JTLS and one for ITEST) was prone to synchronisation problems, had the potential for data mismatch, and did not allow the exercise planners much flexibility to dynamically change the course of events. In short, the solution worked, but required quite a bit of effort to set up and to keep events and data synchronised.

Another issue that arose during CC02 was an appreciation for the huge number of entities required to accurately reflect background traffic for the AGS simulations. If not managed properly, these entities would quickly swamp computer and network resources.

The typical model-to-model interoperability issues were also encountered. Although HLA was used as the interface between JTLS and EADSIM, both simulations lacked FOM agility. This resulted in a FOM that was driven more by what the models could be made to easily produce than by the CC02 exercise requirements. The developers of both tools were needed to achieve a functioning federation, and specialised software versions were created. While the TMD objectives for the exercise were met, it required a large investment in time and manpower to achieve. These issues are by no means peculiar to these models or this exercise. In our opinion, they represent a common set of challenges that are faced in most distributed experiments and exercises.

3.0 VISION FOR THE FUTURE

CC02 is only one example of the many types of activities the MD Branch is requested to support with M&S and prototyping. It is a useful example in that it brings attention to the various problems and challenges associated with M&S support for large scale, distributed exercises. However, as mentioned previously, it is also illustrative of the constraints that any future M&S activity is likely to encounter. Some of these constraints include:

- Exercise/experiment specific goals, objectives, and requirements.
- Limited NC3A manpower and specialised expertise.
- A mixture of DIS and HLA compatible models and prototypes.
- For HLA compatible models and simulations, the SOMs will almost certainly not map directly to each other.
- Lack of access to source code and/or simulation developers.
- Potentially large number of entities (especially for AGS applications).
- Never enough time.

These must all be taken into account as we formulate our vision for a missile defence interoperability testbed at NC3A.

3.1 The NC3A Missile Defence Interoperability Testbed

The overall objective of the NC3A Missile Defence Interoperability Testbed is to create an environment for addressing missile defence interoperability issues in the near-term. We want to create an environment where the M&S interoperability issues are addressed up front and independent of any particular exercise or experiment. We want these issues resolved in a way that allows our analysts to focus on the branch's primary functions of::

- Verification and validation of NATO's command and control concepts of operations for missile defence.
- Identification and evaluation of missile defence C2 system requirements.
- Test and evaluation of missile defence prototype software.
- User-in-the-loop concept evaluation.

The testbed should provide an environment that allows us to perform these functions without creating an unduly large burden on the branch. In other words, the testbed should support the existing objectives of the Missile Defence Branch and NC3A, and not become an objective in and of itself.

This environment will also need to support all three of the major types of activities that the branch performs. These activities as described previously include, Studies and Analyses, Prototype Development, and Exercise/Experimentation. The testbed must support all three types of activities and provide as much commonality as possible to ensure the smooth transition from one activity type to another, while minimising training and manpower costs.

NATO is currently tasked with providing an effective missile defence of its deployed forces. It must perform this mission using an assortment of weapon and sensor systems provided by the NATO member nations. With this in mind, it is easy to see why operational, system, and technical interoperability are among NATO's highest priority challenges. The focus of the Missile Defence Branch, and therefore this testbed, is on missile defence interoperability issues associated with real-time and non-real-time C2 functions. The testbed must address and facilitate the identification of data exchange requirements, the exploration of potential synergy between the functional areas of missile defence, and the raising of real-world, missile defence BMC3 issues before weapon, sensor, and C2 systems are fielded in an operational setting.

The testbed vision described in this document addresses a specific, near-term missile defence need within NATO. One of the conclusions coming out of NATO's Active Layered Theatre Ballistic Missile Defence Feasibility Study (ALTBMD FS) is the need for a testbed to reduce the schedule risks associated with the integration of a variety of weapon, sensors, and BMC3 systems. By establishing a distributed testbed capability, integration and interoperability issues can be identified and resolved well in advance of system fielding. As part of the Capability Package resulting from the ALTBMD FS, an Integration, Test, and Evaluation Testbed is being proposed with an estimated 2006 IOC date.

The problem with this is that NATO's primary C2 systems that will be used to plan, task, and execute the missile defence mission (ACCS and Bi-SC AIS) are in development now with the initial missile defence requirements being analysed and developed over the next couple of years. Also, within the operational community, the missile defence CONOPS are currently being refined and evaluated to deal with ballistic missiles of extended ranges and WMD capabilities. The testbed vision described in this paper addresses these near-term needs in support of NATO C2 system requirements capture and military CONOPS development, and is envisioned as a bridge to the future integration testbed defined in the ALTBMD FS Capability Package.

Our vision of a useful testbed is more than just a collection of models that can exchange information with one another. It includes the following dimensions:

- Facility related infrastructure.
- Hardware related items.
- Core simulations and models.
- Prototype software.
- Distributed simulation capability and support infrastructure.
- Analysis tools.
- Support staff and training.
- NATO reference databases.

Each of these areas will be addressed in more detail in the following sections.

3.1.1 Facility related infrastructure

The facility supporting the testbed should be able to handle NATO security levels up to and including NATO Secret. It must allow repeated access to military and technical representatives from NATO member countries and their equipment, and have the necessary NATO network connections to allow remote participation in NATO experiments and exercises.

3.1.2 Hardware related items

The missile defence interoperability testbed should have a robust hardware suite available to it. This hardware suite must support prototype and model hosting, a centralised server capability, sufficient storage and network capacity, communications interfaces to distributed locations, as well as a well-documented and tested backup system. The objective here is to have the required hardware capability and system administration processes developed and in place before (and independent of) any specific exercise. This will provide a stable, familiar, and well-documented computing environment for conducting missile defence experiments and exercises. It will also reduce the need and associated risk of trying to acquire computing and network hardware to support a specific event.

3.1.3 Core simulations and models

The interoperability testbed can be thought of containing two broad categories of simulations. The first category can be described as "core" tools that model theatre level interactions and effects. Because of the limited amount of available manpower, this set has to be reduced to a relatively small suite of models that must cover a range of capabilities and functions. These models must support studies and analysis, prototype development, and exercise/experimentation objectives. In addition, they must be able to exchange information with each other either by common data structures in support of analysis efforts or by distributed simulation techniques such as HLA (High Level Architecture) or DIS (Distributed Interactive System) in support of experimentation.

The second category can be described as weapon, sensor, and C2 system emulators. These will vary from experiment to experiment and will often be supplied and supported by technical experts from NATO member nations. This set also includes actual weapon and sensor system hardware. This category of simulator/emulator is distinguished from the previous set of models and simulations in the following ways:

- The emulator functionality is narrowly focused on the functions of the system it is representing.
- NC3A will almost certainly not possess expertise in using the emulator.
- Like the theatre level simulations access to source code is usually not available, but access to technical experts with the ability to make code changes on the fly is not unheard of.

In general, these emulators will be available for a short time to support the specific exercise or experiment, and will then be removed.

3.1.4 Prototype software

One of the fundamental objectives of this interoperability testbed is to provide an environment for stimulating and testing NC3A's missile defence prototype software. The prototypes follow a spiral development process that requires continual interaction with the military operations community with stimulation from realistic representations of the weapon and sensor systems they will be controlling. The following attributes describe how the NC3A prototype software differs from the models and simulations described in the preceding section:

- Access to source code (primarily written in Java)
- Continually changing software in response to emerging operator requirements
- Prototype developers are not necessarily HLA or DIS experts

By facilitating the running of experiments using NC3A's missile defence prototype capabilities, more frequent iterations can be made in the spiral development process, and requirements capture can be achieved more rapidly.

3.1.5 Distributed simulation capability and support infrastructure

A distributed simulation capability is a prerequisite for the interoperability testbed. The testbed must allow for the inclusion of legacy systems still using DIS, but should be based upon HLA and take advantage of the benefits it provides. A FOM that is specific to the needs of the missile defence mission area should be defined, and the core models should be made to conform to it. A customised FEDEP (Federation Development and Execution Process) should be developed for the interoperability testbed taking into account its core capabilities and reoccurring elements and processes.

One particularly important aspect of this distributed simulation capability is the way in which tactical data links (TDLs) are represented and accessed. TDLs are the basic information exchange methods by which NATO's operational and technical elements communicate with each other. They are standardised and baselined in NATO Standardization Agreements (STANAGs) signed by the NATO member nations. The interoperability testbed must reflect these communication standards to ensure that modelled systems are constrained in the same way that real-world systems are.

Finally, in-house HLA expertise and a set of network/HLA diagnostic tools are necessary, as debugging and analysing distributed experiments can be extremely difficult and time consuming.

3.1.6 Analysis tools

A common set of tools designed for distributed experiment analysis is necessary to efficiently collect, reduce, and display the results of an experiment. This is particularly important for experiments and exercises where a large number of people are involved. As distributed experiments tend to generate large volumes of data spread across multiple computers, this can also be a very challenging task. The chief objective here is to allow people to spend their time addressing, analysing, and discussing the experiment results, not waiting for the results to be collected and displayed. The ability to quickly and succinctly generate "After Action Reports" would also be extremely useful.

3.1.7 Support staff and training

To run this testbed effectively, a team of trained and experienced staff are necessary. As staffing levels are always lower than desired, the testbed support staff needs to consist of flexible individuals with expertise in multiple areas including: technical management, core simulation expertise, HLA/DIS federation construction and execution issues, as well as computer hardware, software development, and network experience. These individuals must also be able to effectively communicate with technical staff supporting other event specific applications as well as personnel from the military operational community

3.1.8 NATO reference database

The final dimension that makes up our vision of a missile defence interoperability testbed is access to a well-defined and sanctioned set of NATO reference databases. These databases include environment models (e.g., terrain, standard atmosphere, earth spheroid, etc) as well as threat representations, weapon/sensor system models, and standard scenarios blessed by the NATO military staff. In addition, these databases should include reference architectures, command structures, and BMC3I models for NATO ACCS and Bi-SC AIS entities. These databases must be accessible, controlled, and maintained. The objective is to have the desired data, ready to go, with no development or set-up time required.

3.1.9 Potential software and network components

Having addressed some of the general features of our testbed vision, it is now useful to look at some potential software and network components to start to get more specific and identify a roadmap for achieving our vision. Figure 4 above shows the different categories of models, simulations, and software tools and reinforces some of the points made in the previous discussions. The important thing to note is that any particular exercise or experiment will contain only a subset of the elements listed. The key then is to identify a set of core models and a flexible infrastructure that will facilitate the inclusion of a variety system emulators and prototypes.

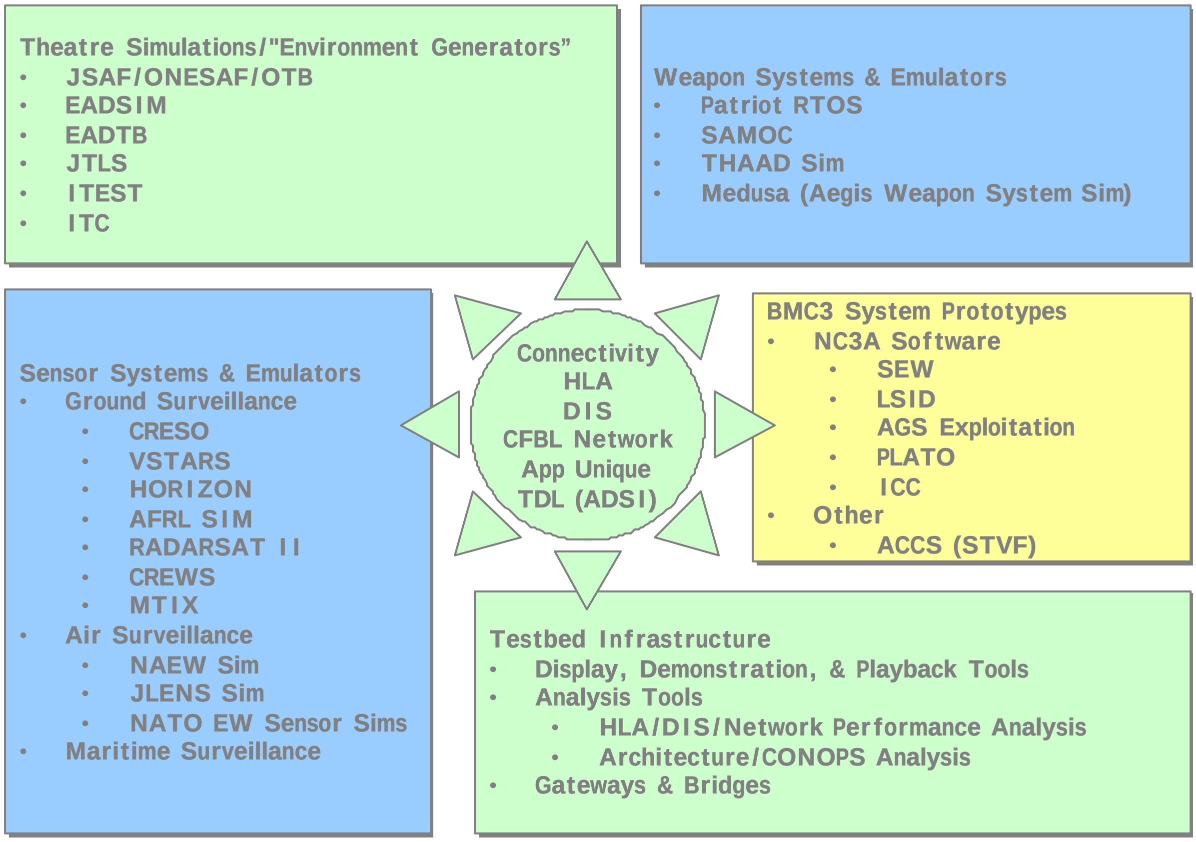

Figure 4: Different categories of models, simulations, and software tools for the testbed.

As we move to a more specific vision of the future, it is also useful to think about how the NC3A Missile Defence Interoperability Testbed will relate to the ACCS System Test and Validation Facility (STVF) as well as national test facilities. Our vision is that the NC3A Missile Defence Interoperability Testbed will provide a fundamental part of the Integrated Test and Evaluation Testbed when it comes on-line in the 2006 time frame. Connecting operational prototypes at NC3A with the ACCS system software at the STVF and weapon and sensor simulations at national facilities will allow NATO to explore new C2 CONOPS as well as validate technical information exchange requirements and implementations.

3.2 NC3A HLA Initiative - Objectives & Goals

So far we have discussed our overall testbed philosophy and vision. We have also provided a brief description of what we think our testbed will look like in the future and how it will relate to other missile defence testbed facilities that exist or are planned. However, before concluding, we would like to discuss two current, on-going activities that are aimed at taking concrete steps towards achieving our vision of a missile defence interoperability testbed.

The first activity is the HLA Testbed Initiative that is being conducted by the Missile Defence Branch and TNO. The project's primary objective is a report summarizing a set of recommendations for the development of an HLA federation to support NC3A's Missile Defence Interoperability Testbed. This report is to be accompanied by a proof-of-principle experiment demonstrating the viability of the report's recommendations. Specific areas addressed by effort are: FOM agility options for simulations developed by 3rd parties, RTI selection, and ways to facilitate HLA-enabling of the branch's JAVA-based prototypes. The proof-of-principle demonstration will include EADSIM, EADTB, LSID, and the SEW display software. EADSIM and EADTB represent the category of large, theatre-level simulations that are deployed without source-code and have differing HLA implementation approaches. The LSID and SEW software represent the class of federates that are developed by NC3A. These NC3A developed prototypes can be modified, and their inclusion is meant to test the ease with which they can be integrated into an HLA federation. This initiative is close to completion, and will form the basis for the Missile Defence Branch's HLA implementation approach for the Interoperability Testbed.

3.3 MSG-006/TG-006 Participation

The second major activity supporting NC3A's missile defence interoperability testbed implementation is our participation in the NMSG's MSG-006 Task Group. This task group was established to investigate "M&S Support to Assessment of Extended Air Defence C2 Interoperability" in a NATO environment. The task group's objectives include evaluation of the feasibility of reusing existing simulation components and testbeds across NATO in an integrated, distributed fashion. In addition, and perhaps more importantly, the task group will recommend approaches to distributed simulation architectures that will enable extended air defence C2 interoperability analysis. This will include the development of a recommended reference FOM and a FEDEP tailored for extended air defence. While the HLA testbed initiative project addresses issues such as how to get federates to use a common FOM, one of the important products of the MSG-006 task group will be a recommendation on what objects and interactions should be included in that FOM. This is critical if the missile defence analysis community is going to take full advantage of the benefits that HLA can provide.

4.0 SUMMARY

In summary, NC3A depends heavily upon the use of modelling and simulation to support missile defence C2 interoperability analyses for NATO. Experiences at Cannon Cloud '02 and other similar NATO exercises demonstrate the need for a missile defence testbed that allows analysts to focus on the C2 interoperability issues rather than the M&S interoperability issues. For this to occur, a set of objectives and requirements for a testbed environment is needed and must be followed by a concerted, focused implementation effort. The Missile Defence Branch has identified what such an environment would look like and is involved in specific activities that are aimed at achieving it.

Exploiting Virtual C4ISR Simulation in Training Decision Makers and Developing New Concepts: TUBITAK's Experience

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Abstract

In this paper, TUBITAK's (Technical and Scientific Council of Turkey) experience in C4ISR domain and a simulation tool being developed are summarized.

1 Introduction

Nowadays, C4ISR as an integrated military structure attracts more emphasize in parallel to developments on information technologies and knowledge engineering. C4ISR systems merge both physical components and information-oriented aspects like decision-making and message exchange between participating components. Combining both world layers, physical and information, provides wider worldviews allowing modelers and analysts to design inclusive and comprehensive defense simulation tools addressing war games, C2 analysis, concept development and gaining management experiences on them. In simulation literature, information and physical items flows are known as opposite to each other. Bringing both flows together and satisfying analysis requirements of being together is not an easy task making more elegant modeling approach especially for reusability, modularity and interoperability, mandatory. As an integrated and complicated domain, the problem of C4ISR concepts development as well as staff training generally requires experimenting on complex scenarios. Simulating these scenarios in virtual environments and coupling them to real C4ISR systems and staff is significantly cost-effective solution for the problem [1].

From the simulation point of view, modeling information layer is pretty different from modeling physical layer. Variety of information types, concurrency, probabilistic nature of information and its flow among operational nodes, in addition to all, infeasibility of fully automated decision making as well as data fusion make modeling a very complicated task. So, that requires knowledge intensive and highly autonomous components in addition to well-formulated mathematical models solvable by operational research methods. This reveals man-in-the-loop simulation as a practical solution for the problem. That is one of the essential factors for planning C4ISR simulation tools interacting with human in run time.

Paper presented at the MSG-022/SY-003 Conference on "C3I and M&S Interoperability", held in Antalya, Turkey, 9-10 October 2003, and published in RTO-MP-MSG-022.

TUBITAK is developing an open, reusable, modular and interoperable simulation system for modeling and executing C4ISR architectures. This paper summarizes the lessons-learned up-to now and relevant projections for future. The simulation system has an open architecture on two points. The first point is generating a distributed infratructure consisting of reusable components. This is achieved by setting up the whole system on HLA/RTI middleware; it is possible to insert external simulation or software components, even in run-time to a scenario which is being executed as a federation as well as deploying the components in other HLA federations. The other point emphasizes openness to new developments by having modular and well-interfaced component architectures.

The system could serve for concept development, analysis and training purposes. Military Concept development is achieved by being able to try different scenarios. They consists architectures of C4I and SR components allowing declaration of operational information flow among each other. Results of scenario execution are elaborated using the analysis functions of the system. Analysis outcomes are revised to restructure the scenario for better architectural concepts. The analysis has done in two ways; in the classical way, as is the simulation post-data analysis, and the second way, optimization for component behaviors with respect flexibly defined criteria. Moreover, trainees are faced with different cases in scenarios to examine and feedback their strong and weak sides in developing C2 decision and actions.

The following sections present rationale and features of the system.

2 Rationale For C4ISR Simulations

Essential idea behind the C4ISR concept is developing system of entities and their interoperability definitions rather than entities themselves. Hence, the main motivation for C4ISR simulation systems is being able to model many individual and interoperable components into one common integrated virtual environment. Stressing integrated view follows up the need for modeling an environment promoting analysis of architectural concepts as well as decision making of corresponding staff. It could be modeled at different layers of C2 process, that are; modeling multi-sensor and multi-source data fusion, modeling decision support mechanisms, modeling whole C2 staff decision making process as well as modeling behavioral and decision making capabilities of enemy forces. For such analysis, features concerning information and its flow within organizations should be involved within simulation models. By incorporating information, users and analysts could reason about operational success of components, their level of integration as well as amount and quality of data they produce. This includes examining connectivity effectiveness and performance issues about information amount and flows.

Training staff and testing new components in typical and extreme situations within such a broad sense (integrated systems) is costly and in some cases not very practical. As C4ISR scenarios could be developed and executed in virtual environments, training and trials of real elements becomes matter of interfacing the systems to the virtual environments. This provides very efficient way for performance examination of system components in various condition and cases. System acquisition policies could well be established on such tests done using virtual environments.

Strategical and tactical rehearsal of C4ISR systems needs many elements to be fed by exercise context of scenarios belonging to various operational cases. Developing realistic operational cases in peacetime is partly possible. In spite of the fact, nowadays many real-world items could be well-featured using virtual mediums. Consequently, C4ISR modeling and simulation environments offer such realistic resemblence to its real world operational en environmental conditions counterparts. This is used in strategical and tactical rehearsals involving virtual C4ISR context. Strategic and tactical confinement as well as force organizations subject to geo-politic and doctrinal considerations that vary for each country. Virtual simulation environments could be tailored to reflect such doctrinal chracteristics.

3 Purposes Of the C4ISR Simulation Environment

A C4ISR modeling and simulation environment development project is currently being carried on by TÜBİTAK. It involves modeling, simulation and analysis capabilities for various C4ISR architectures emphasizng ISR missions. It will consist of various types of component models running as HLA federates on RTI. Component models will be modular and well interfaced letting cast of different scenarios. The system will allow deployment of C2, Communication, Computer, and ISR component models and definitions appropriate for both physical and information layer. Main features of the system are as in the following.

User could define an integrated operational scheme by having tools to lay down components on the scenario region and specifying their technical and operational capabilities. This will provide the physical layer construction of the scenario. These component models are defined as types of sensors, communication systems, C2 systems and weapon systems. Another definition will involve architectural and operational integration of components under a common command and control structure. There will be definitions on organizational features pertaining to operational, system and technical views of the architecture. This will give information layer designations.

The system will have tools allowing static and dynamic optimization of sensor deployment, their coverage optimization and multi-sensor route planning. User could define cost functions and constraints of performance measures. These mesaures could be defined with respect to the missions of scenario.

Sensor detection, classification and identification data will be integrated using fusion models. There will be two types of data Fusion; sensory and information (commented data) data fusion. This capability will support examining how the fusion concept affect decision makers job. Also testing various fusion approach and techniques would be possible. If required tactical picture based on fused data will be avalibale to C2 staff.

Analysing different C4ISR architectures under various conditions will add measuring effectiveness of architectures in real-time performance, tactical criteria and information format and sufficiency etc. This will enhance peacetime review of organizational effectiveness for contingency conditions.

4 Branches of the simulation environment

The simulation environment consists of “Scenario design”, “Scenario engine”, “Analysis”, “Optimization”, “Autonomous forces”, ” Communication”, “Sensors”, “fusion” and “map functions” main components.

Scenario design tool allows modelers to define scenarios. Scenario definition phase starts with choosing a map in DTED format. Simulation component toolboxes let scenario designer to choice any components and place on the map. The components in the toolboxes are stable and moveable platforms, communication devices, command and control units, personnel (including enemy), fire support units, sensor systems and man-made structures such as milestones, buildings, borderlines, watchman tower and mine fields. All components are in generic form and have their own attributes that can be edited by the scenario designer to translate them into more specific ones. Moreover, getting the components in the scenario more specific, it is possible to equip a component with some other components such as assigning a pistol to a private, to prepare some ready to use scenario components such as route definition, area definition and assign them to related components as subcomponents. Possibly, the most critical definition in scenario design is mission declarations consisting of what component has what goal and how they succeed them. “*What*” part is modeled in mission-task-activity tree structure. Each mission and its tasks have their own “success constraints” and each method of the tasks have their applicability constraints and a process, namely “*How*” part, declaring in what structure the methods are applied. The scenario engine accepts the whole declaration to implement.

Scenario engine is a manager agent expanding component mission definition by watching the simulation environment. It basically checks the task applicability conditions and applies implementation process sending messages related simulation component declaring “what to do” and gets a succeed result back.

To be able to build the scenario in C4ISR structure, architectural definition components are provided to ensure C4ISR completeness of scenarios. Architectural components are summarized under three main headlines. They are Operational view, System view and technical view. In operational view, the environment provides high-level operational concept graphic, in which operational nodes are defined and declared what the simulation components belong to, organizational relationship chart, operational node connectivity description, operational node connectivity diagrams. C2 hierarchies and Commander responsibility area and types are defined by organizational relationship chart.

System view is related with assigning the system to the tasks to do and the communication devices to the messages defined between operational nodes by operational node connectivity diagrams. Technical view provides a series of interfaces providing opportunities creating queries for both applicability checking of activities implemented by a component and suitability checking of a device for a specific task or choosing the better device for it.

Analysis module undertakes two central tasks. The first one is to create simulation input data such as random number values form theoretical distributions, random number streams. The second task is to make queries on execution results and subject to statistical analysis such $\chi 2$, ANOVA. This task is also used for performance analysis.

Cost-effective optimum sensor deployment and sensory platform path planning are main task of optimization tool. Optimization finds optimum sensor combination allowing maximum coverage or optimum sensor combination under some budget constraints. Depending on sensor types, sensor models pick information from environment especially enemy sources and send command layers them via communication devices and command layer make decision fusing the information coming from multiple sources by data fusion algorithms.

Map functions are fundamental for visibility and coverage area computations for both sensors and communication devices. All models in the system are modeled effect modeling approach rather than physical modeling.

5 HLA Compatibility

Each scenario will be a different HLA federation running on RTI middleware. To support this structure, sensor, communication, platform, staff and C2 components are represented as federates. Components could dynamically publish or subscribe object/attribute/interactions during execution.

The system could run in real-time and logical time modes. A separate coordinator federate will manage time and phase synchronization. Also preprocess, execution, post-process and replay functions will be managed by coordinator federate.

Federates are structured in a layered form. Model calculations and federate interface will be separate modules each interacting through interface functions. This will enhance replacing the calculation side with others having different approach and implementation.

On the other hand federated component models could be deployed into separate processors. Higher performance would be achievable when the system is loaded with a complex scenario. Also training features will be promoted by breaking up each federate onto separate computer. Federate user interfaces support this capability. Consequently each C2 federate user/operator could see the tactical picture of its own knowledge base.

6 Usage Concepts

The simulation tool is planned to be used aspecially in four main domains. These are

1) Training,

2) Rehearsal,

3) Analysis and

4) Optimization

In training purpose, users are expected to get insight some fundamental sensor usage concepts. Rehearsal is thought mostly to improve talents of tactical analysis and tactical planning capabilities of users.

The main stress on Analysis module is performance analysis. The aim is to put differences between users forward and to watch their improvements.

Optimization is for planning purposes. The planning consists of deployment of sensors on an area, combination of sensor type and numbers, and movable sensors' path planning so that maximum coverage is satisfied under cost constraints.

7 Results

The main characteristic of the study is the effort to bring together information layer simulation together with the layer in which models of real world physical entities are simulated. This effort matches what C4ISR aims to do.

The simulation tool has the properties enumerated below;

- Hybrid simulation models: discrete and continuous together
- Effective modeling rather than physical modeling
- HLA-based distributed simulation
- Includes an optimization module
- Serves a base for data fusion
- Analysis for both tactical and training

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Training & Education Enhancement Programme (TEEP): Current Status and Way Ahead of Advanced Distributed Learning (ADL) & Simulation Portion

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OVERVIEW

Endorsed at the Washington Summit, confirmed at the Prague Summit, the Training and Education Enhancement Programme is viewed as a useful tool to achieve interoperability and considerable progress has been made in several areas in the past year, especially in its Advanced Distributed Learning and Simulation component. A number of studies have been completed with the expertise of the RTA/NMSG, the NATO Training Group (NTG) and others in support of NATO Strategic Commands, with Allied Command Transformation (ACT) in the lead.

The ADL prototype is considered a success and the establishment of a NATO/PfP ADL capability supporting NATO/PfP Education and Training is feasible. ACT has been requested to propose a course of action to implement it, including the continuation of the prototype use with National contributions until a Capability Package (CP) is developed.
It is feasible and cost-effective to use distributed simulation for training. ACT has been requested to propose a course of action to implement it through the execution of a set of distributed NATO/PfP prototype exercises, and the development of a CP including a successor of Allied Command Europe (ACE) Command and Staff Training Programme (ACSTP).

BACKGROUND

The December 1998 North Atlantic Treaty Organisation (NATO) Ministerial meetings tasked the North Atlantic Council (NAC) to identify and consolidate initiatives underway in Partnership for Peace (PfP) in order to form a coherent package of measures to reinforce PfP's operational capabilities. Education and training activities such as the PfP Training Centres, the PfP Simulation Network and the PfP Consortium of Defence Academies and Security Studies Institutes were identified as appropriate subjects for consolidation.
During the April 1999 NATO Summit in Washington, Heads of State and Government endorsed the resulting PfP Training and Education Enhancement Programme (TEEP).

The TEEP is to provide a structured approach to optimise and improve training and education in the Partnership to meet the current and future demands of an Enhanced and More Operational Partnership (EMOP), focussing specifically on the achievement of interoperability.

Paper presented at the MSG-022/SY-003 Conference on "C3I and M&S Interoperability", held in Antalya, Turkey, 9-10 October 2003, and published in RTO-MP-MSG-022.

This paper reflects the author's personal views on the subject

The TEEP programme was re-endorsed during the November 2002 NATO Summit in Prague, where the Alliance took the decision to upgrade NATO co-operation with the EAPC/PfP countries and highlighted the requirement to continue to further enhance NATO/ PfP interoperability as part of the transformation agenda. Critical to this approach is the need to support the development of Combined Joint Task Force (CJTF) headquarters and to expand the strategic reach of the co-operative building effort to include Central Asia and the Caucasus.

The TEEP programme encompasses six components:
- linkages and collaboration;
- feedback and assessment mechanism;
- interoperablity;
- exercises;
- national training and education strategies;
- advanced distributed learning & simulation (ADL).

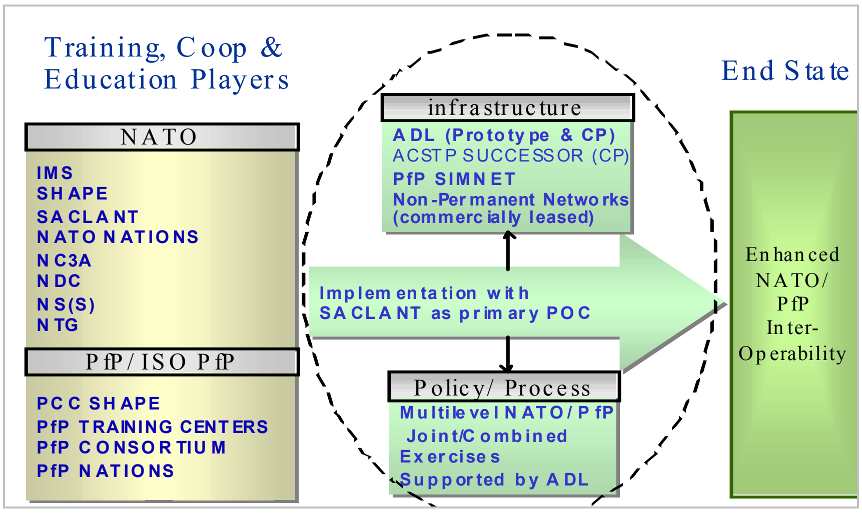
This document will focus on the latter component only.

THE VISION

To implement Prague Summit mandates in strengthening NATO-PfP education and training collaboration as part of the transformation agenda, it is essential to build upon existing efforts, and only where necessary to explore the need to establish new information technology capabilities. The desired long-term end state vision is to provide Allies and Partners with a multinational training and exercise environment up to the CJTF "command and staff" level, supported by a near-real-time interactive ADL and Simulation environment that:
- Supports combined, joint operations;
- Links military, political-military, and civil-military components into simulation, modelling and training;
- and, Integrates such distributed training with focused professional military education delivered through ADL.

It is worth noting that the strengthening of NATO-PfP education and training not only benefits Partners, but also NATO Nations and the Alliance as a whole.

The studies highlight that there is not yet a single, coherent strategy nor an implementation plan that links and co-ordinates existing key agencies within NATO and PfP to achieve enhanced interoperability and which satisfies NATO and Partner requirements for training and education in NATO-led, Non-Article 5, combined, joint operations down to the battalion level. The key agencies, infrastructure and processes that should be linked and co-ordinated to reach those objectives are illustrated as shown at the figure below:



Note: IMS International Military Staff; SHAPE Supreme Headquarters Allied Powers Europe; SACLANT Supreme Allied Commander Europe, recently renamed ACT Allied Command Transformation; NS(S) NATO School (SHAPE) recently renamed NATO SHAPE (Oberammergau); NTG NATO Training Group;PCC Partnership Co-ordination Cell

The Washington Summit TEEP-related initiatives of PfP Training Centres, PfP Simulation Network and PfP Consortium of Defence Academies and Security Studies Institutes continue to form an interlocking and coherent package of measures to reinforce PfP's operational capabilities. To implement Prague's direction to intensify this effort in support of Transformation, explicit NATO counterpart efforts need to be identified and reinforced. Among the benefits that the nations may expect to receive in return from this collaboration with NATO is higher levels of interoperability, including the capability to co-evolve organisation, command concepts and doctrine among the many nations that will be sharing advances in technology.

The figure below summarises the necessity to align on-going PfP TEEP activities referred to above with their corresponding NATO counterpart: a NATO Distributed Simulation initiative, NATO School (Oberammergau) (NS(O)), and the NATO Defence College (NDC). In addition the figure highlights the needs to create a permanent nucleus at ACT to co-ordinate NATO-PfP ADL & Simulation efforts. These ideas comprise the central elements of the NATO-PfP training transformation effort that can be supported by Advanced Distributed Learning and Distributed Simulation capabilities. Implementation of this vision is enabled and supported by the links established with the TEEP- related Training and Education Initiatives, which have been instrumental in bringing diverse training and education communities into a mutual support framework.

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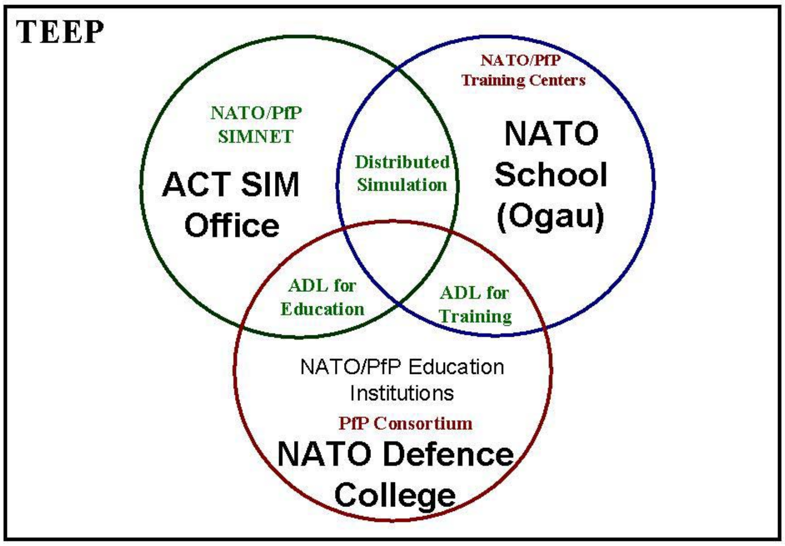
Mutual Support Activities



A MULTINATIONAL ENVIRONMENT

Since their establishment at the April 1999 Washington NATO-EAPC Summit as "new tools" in support of NATO-PfP interoperability, the PfP Consortium of Defence Academies and Security Studies Institutes, the PfP Simulation Network, and PfP Training Centres have flourished.

As "in the spirit" of PfP activities, they have benefited from the convergence of national and multinational support, while remaining free from subordination to any particular national agenda or direct NATO involvement. Driven largely by the principle of voluntarism, they provide a unique, mutually supporting venue for concept development and experimentation. Exploring new approaches to security cooperation and interoperability, they analyse lessons learned and help to share best practices.

Consequently, these three major "tools" of TEEP provide a foundation for NATO-PfPtraining transformation, consistent with PfP's principle of "self-differentiation," whereby nations determine for themselves what they wish to contribute or to receive. Collectively they assist in the development of a cooperative network of security institutions.

PfP Consortium of Defence Academies and Security Studies Institutes
The PfP Consortium constructs new tools to support collaborative learning between nations and is at the origin of NATO's own capabilities in critical transformation areas. It provides a unique example of international cooperation in the multinational development of e-learning applications for security cooperation. The end state vision of a virtual multinational learning environment that links military, political-military, and civil-military components into distributed modelling and simulation environment supported by focused professional military education is a realistic goal attainable in collaboration with the Consortium's core ADL development capability.
Switzerland's support through the PfP Consortium has been a critically important element. Swiss teaming arrangements with Allies employing the ADL Co-lab SCORM standard was

This paper reflects the author's personal views on the subject

the principal factor in the development of technical tools and learning material for NATO/PfP ADL. Switzerland further provided the leading support in coordinating and integrating Voluntary Contributions by joining a wide array of PfP Consortium experts from throughout the EAPC region through the PfP Consortium's ADL, Simulation and Curricula Working Groups. As NATO implements the Prague Summit mandate for EAPC-PfP activities, an essential element in the success of the NATO-PfP transformation effort will be to ensure the preservation of distinctive Partner nation lead roles and responsibilities and align them in a corresponding relationship with the NATO Defence College.

PfP Training Centres

Nine Allied and Partner Nations participate in providing PfP Training Centres, most of whom focus on operational and tactical level training and instruction in NATO/PfP staff procedures and other individual skills. NATO has a link to them through the NATO School (Oberammergau), and they agreed in their last Conference of Commandants to increase their role in ADL and Simulation development in support of enhanced NATO/PfP Interoperability.. Increased attention to advanced distributed learning and distributed simulation shared among and between the Centres could lead to new synergies, leverage and multiply the use of scarce resources, and produce greater operational readiness as part of an enhanced training transformation capability. Transformation of courses can be usefully supported in having PfP Training Centres and Co-operative Development Teams work together, as Turkey plans to do, for instance.

PfP Training Centres are assessed to be an essential source of insight and guidance on the harmonization of curricula and could help in developing and sharing ADL courses and joining in Distributed Simulation Command Post Exercises (CAX) under the auspices of the PfP Simulation Network, or in a Distributed Defence and Wargaming Simulation approach in tandem with the PfP Consortium. In support of the NATO-PfP ADL and Distributed Simulation effort, NS(O) could be strengthened to perform a ADL/SIM clearinghouse function among the PfP Training Centres and provide another mechanism for including Partner nations in the Transformation agenda.

PfP Simulation Network

The PfP Simulation Network initiative has developed on a regional-basis (e.g., Southeast Europe Simulation Network (SEESIM), Baltic Simulation Network (BALTSIM), et al), joining in mutual collaboration approximately twenty Nations. Like the ADL effort, where one Partner nation (Switzerland) has led the effort in mentoring other nations, Sweden has been at the forefront in developing and promoting Distributed Simulation as a core capability connecting Allies and Partners, employing in particular the "Viking" series of exercises. This effort, however, is not presently linked with any NATO permanent office to distribute simulation and this is another area of ongoing activity that is of great potential benefit to the Allied Command for Transformation.

Transformation: Building Upon Complementary Efforts to Attain New Synergies

The Prague Summit Declaration statement concerning cooperation with the EAPC/PfP countries directs that "Allies, in consultation with Partners, will, to the maximum extent possible, increase involvement of Partners, as appropriate, in the planning, conduct, and oversight of those activities and projects in which they participate and to which they contribute." This means that efforts such as the PfP Consortium, PfP Training Centres, and PfP Simulation Network may benefit of greater Partner direction and control. At the same time, a strengthening in the participation and linkage of NATO counterpart activities could complement the integration and mutual support effort. Respectively, the NATO Defence College, the NATO School (Oberammergau), and the NATO-PfP Distributed Simulation Capability Initiative (DSCI) are equally important in the overall transformation vision to attain new synergies in the quest for enhanced interoperability and strengthened security cooperation throughout the Euro-Atlantic region.

MAIN CONCLUSIONS

On Advanced Distributed Learning:

ADL capability has enormous potential. The NATO / PfP ADL Program can contribute to further increasing readiness by providing high quality, interoperable, and sharable education and training anytime and anywhere, while improving military effectiveness and efficiency. ADL might become a prerequisite to attending a course, thus ensuring the proper level of training has been reached by the trainees. The Sharable Courseware Object Reference Model (SCORM) concept provides a basis for the development of ADL modules to be freely shared among institutions and nations in support of interoperability and reusability. The NATO/PfP ADL prototype has provided an immediate ADL capability to NATO and PfP nations, resourced by Voluntary National Contributions (VNCs). In particular, the “Introduction to NATO” - the first course in the prototype – has been considered by users as useful, well prepared, and an excellent way to introduce, refresh or update students on that subject. In general the ADL Prototype has been assessed as easy to use and valuable; moreover, there is a strong request for the provision of more courses. The establishment of a permanent Operational NATO/ PfP ADL capability supporting PfP and also NATO education and training is feasible.The ADL prototype should be extended, resourced by VNCs, to form an Initial Operational Capability that will continue providing an immediate ADL capability and service to NATO and PfP nations, and will form the basis for specifying the procurement, via standard NATO Capability Package procedures, of an Operational NATO/PfP ADL Capability.

To meet the request for new ADL material the national Co-operative Development Teams (CDT), trained under the auspices of US-Swiss support to the PfP Consortium of Defence Academies, have to continue their crucial activity of transforming traditional courses into ADL supported courses. It is also anticipated that NATO and PfP Educational Institutes should become producers of ADL courses and material.There is a need to enhance the ADL capability of NATO education and training organisations. The establishment of ADL ”Chairs” in NDC and NS (O), as well as one Co-operative Development Team for both Institutions are key factors to harmonise ADL work and populate their portal. This capability should be provided as part of a new VNC in terms of the provision of qualified technical personnel in support of PSE’s devoted to TEEP ADL/SIM implementation, with equal contributions from both Allies and Partners.The future Operational ADL capability for NATO/PfP Education and Training should be located at ACT and supported by NATO Education Institutes (NDC, NS (O), NCISS), PfP Training Centres and the PfP Consortium of Defence Academies. The training provided by these institutions and their requirements varies considerably, and it is more effective to achieve ADL capability by establishing each of these organisations and PTCs as “Centres of Excellence” in NATO/PfP ADL.

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Development and administration of a common knowledge portal, will be a continuous requirement.

The continuing use of Voluntary Contributions is assessed as being instrumental for success until a clear definition of a capability package (CP) can be made for ADL and Simulation. Contributors in the development of the ADL prototype deserving a particular mention are:
The PfP Consortium of Defence Academies and Studies Institutes that delivered, through support provided by Switzerland and the US ADL Co-lab (employing the SCORM standard), the technical tools for the highly successful NATO/PfP ADL Prototype.
Switzerland whose wider involvement through its support to the PfP Consortium of Defence Academies has been a critically important element in the NATO-PfP ADL success story.

A permanent establishment of a NATO-PfP ADL Advisory Board should be a priority task, with relevant NATO educational and training institutions drawn into a supporting framework with TEEP PfP activities, as well as with key National representatives who may be involved in providing Voluntary National Contributions. Allied Command for Transformation should develop and co-ordinate appropriate terms of reference for MC endorsement.

It is also noted that some of the PfP countries do not yet have the desired level of Internet access, particularly in the Caucasus and Central Asia. It has been identified that this concern might be met in using the Virtual Silk Highway Project. Collaboration with the Virtual Silk Highway Project through the National Research and Education Network, as well as exchange of information between the IMS and the IS Public Diplomacy Division should therefore be continued.

On Modelling and Distributed Simulation:

There is a requirement, expressed by PfP Nations, for NATO to sponsor a formal programme that assists Partners to facilitate their capability to participate in NATO-led, Non-Article 5 operations. The envisioned programme will provide training and education up to and including in a Combined Joint Task Force (CJTF) staff. This will benefit NATO as well.

It is technically feasible and highly desirable to meet this requirement through the conduct of NATO-led, combined joint exercises using distributed CAX and associated ADL to a key number of PfP Staffs and Simulation Centres.

NATO does not currently have an exercise programme which is sufficiently comprehensive to provide the opportunities or infrastructure as stated above.

A formal phased NATO/PfP ADL and Simulation programme could be implemented by integrating existing NATO resources with additional identified VNCs, which will provide cost-effective training opportunities for Partners to develop and practice NATO-PfP Interoperability for combined and joint operations using distributed CAXs, with ACT being in best position to provide oversight.

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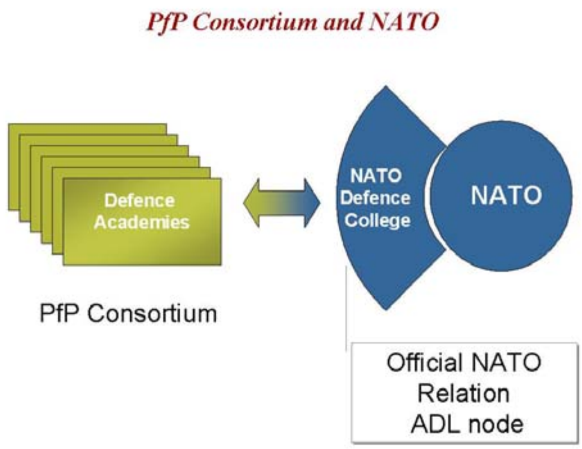
ACT, as the Allied Command for Transformation, with the support of NATO Education Institutions, such as NDC, NS (O), and NCSIS, is best suited to be responsible for the creation and maintenance of the overall NATO-PfP Training and Education Programme, including ADL and Simulation efforts.
Experience gained during the development of the first phase of that NATO-PfP Training Programme could form the basis for ACT to specify the procurement, via standard NATO procedures, of an Operational Capability for NATO and PfP which integrates NATO/ PfP Distributed Simulation to a future Leadership Staff Training Programme (successor of ACSTP).

On the links between NATO and the PfP Consortium of Defence Academies:
A recommendation on the revision and strengthening of this link will form part of the Progress Report on TEEP that will be provided as NMA advice in the framework of the preparation of the Spring Ministerial.

The NDC role as NATO's focus with the PfP Consortium has proven useful in keeping NATO apprised of the activities of the Consortium. NDC's active involvement in participating in numerous working groups, in particular the Secretariat Working Group, has likewise helped the Consortium. NDC should continue to represent NATO in any deliberations concerning the evolution of the Consortium, especially in regard to the NATO-PfP interface on educational and research requirements.

The NDC, in collaboration with the PfP Consortium of Defence Academies, should become responsible for ADL course contents at the strategic and political-military education level, as depicted below:



On the links between NATO and the PfP Training Centres:
The NS (O) in collaboration with PfP Training Centres should become responsible for ADL course contents at the military operational training level.

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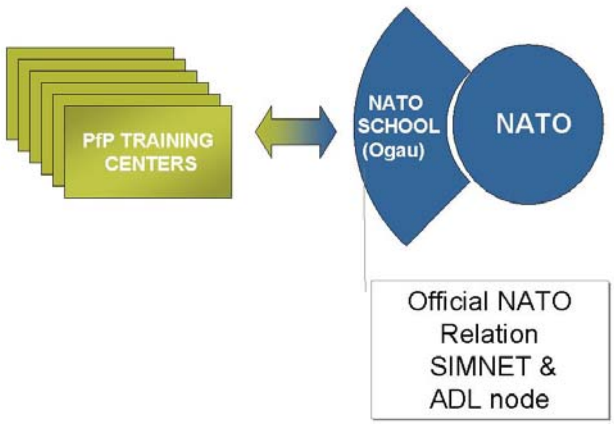
The NS (O) role in relationship to PfP Training Centres should be strengthened with the view to facilitate the integration of operational training and educational requirements in support of ACT (Allied Command for Transformation).

The PfP Training Centres are assessed to be an ideal source of insight and guidance on the harmonisation of curricula and producers of ADL material.

PfP Simulation Centers and NATO



On the links between NATO and the PfP Simulation Network:
Allied Command for Transformation (ACT) should establish a NATO-PfP Distributed Simulation Capability Initiative (DSCI) and a Programme Office to be responsible for Distributed Simulation issues at both the strategic and operational level. DSCI should integrates NATO/ PfP Distributed Simulation to a future Leadership Staff Training Programme (successor of ACSTP)

The ACT DSCI office should work in collaboration with the NDC and the PfP Consortium in exploring opportunities to strengthen defence gaming and simulation capabilities at the strategic level.

The ACT DSCI office should work in collaboration with the NS (O) and the PfP Training Centres in exploring opportunities to strengthen distributed simulation capabilities at the operational level in support of the CJTF concept.

The figure below shows how the Simulation Centres might be interlinked with NATO.

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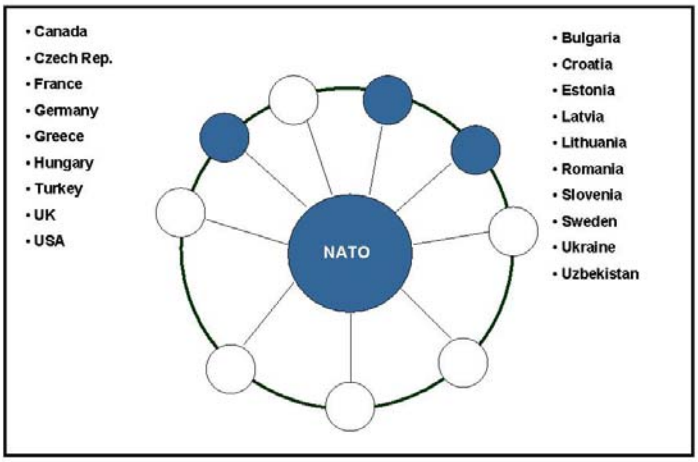
NATO-PfP Simnet

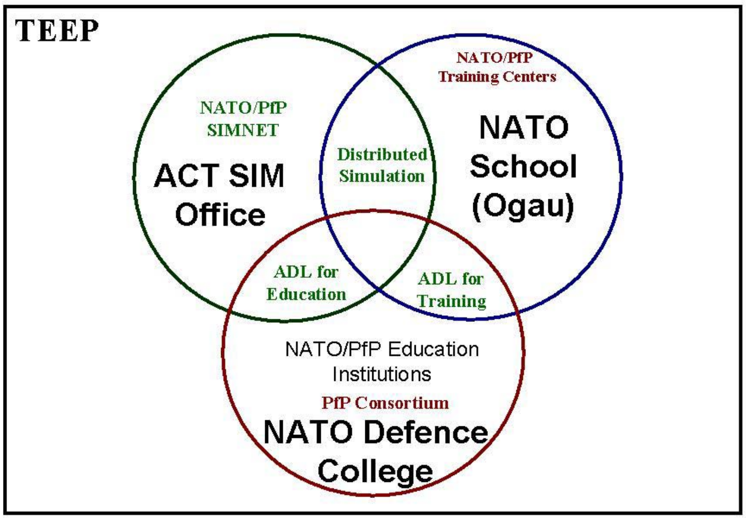


On the structure:
ACT should become the single focus for NATO and PfP ADL and Simulation in NATO and responsible for the creation and maintenance of the NATO-PfP Training and Education Programme, maintaining a close collaboration with SHAPE.

ACT should establish a core capability to implement the ADL strategy and to provide guidance in Distributed Learning and Simulation and to be the permanent organisation to administer, manage and co-ordinate ADL & Distributed Simulation in NATO and harmonise with PfP Nations and PfP Training Centres.

The key agencies, infrastructure and processes might be interlinked as follows:

Mutual Support Activities



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WAY AHEAD

On Advanced Distributed Learning.
The ADL prototype established under ACT has been evaluated throughout 2002 thanks to National Contributions from Allies and Partners, and with the continuous support of RTA/NMSG. It has been concluded that the prototype is valid, and NATO therefore recommended the development of a permanent TEEP ADL capability in support of NATO/PfP Education and Training.
ACT and SHAPE have been requested to make proposals regarding the development of a capability package by Spring 2004, that could be implemented mainly through the continuation of current VNCs.

On Modelling and Simulation.
ACT and SHAPE analysis concluded distributed simulation has an important potential to facilitate the training of staffs, up to CJTF level and to contribute enhancing interoperability at lower operating costs. Currently, a number of national realisations, such as VIKING, BALTSIM or SEESIM exercises could meet PfP requirements up to multinational brigade level. However there are no existing opportunities at the Component Command and CJTF levels.
Establishing a complete NATO/PfP simulation capability at all training levels would go far beyond NATO's investment capabilities. Therefore, existing national realisations should be used through specific agreements. To this end, as a trial, NATO will be represented in the next VIKING exercise in December 2003.
NATO could concentrate on the establishment of a specific simulation capability at the CJTF level, and support lower operational levels. It has been assessed that such a capability should be feasible and affordable.
ACT and SHAPE have been requested to make proposals regarding the development of a capability package, together with a set of distributed NATO prototype exercises by Spring 2004.

CONCLUSION

Considerable interest has been addressed to TEEP since the Washington Summit. The Prague Summit, known as the "Capabilities Summit" paved the way for implementing the programme, in re-endorsing it.

The International Military Staff has now nearly completed the policy part of the work, thanks to the contribution of a team of many NATO and Partners individual and bodies, of which ACT, the NDC, the NS(O), the US JFCOM, the Swedish Wargaming Centre, the RTA/NMSG and the International Staff' contributions have been instrumental for success.

ACT and SHAPE are currently devoting considerable efforts in developing capability packages for ADL and for Simulation sub-components, so that this becomes reality.

They can only have success if real commitments are decided between NATO, PfP, regional and national contributions.

This paper reflects the author's personal views on the subject

ESTHER

Environnement Synthétique de Théâtre pour l'entraînement des postes de commandement

HLA Synthetic Environment Framework for Command Post Exercises

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RESUME

Le déploiement en cours du SIR, Système d'Information Régimentaire (SIR) destiné à couvrir à la fois le niveau régimentaire (Bataillon) et unité élémentaire (Compagnie), implique de revoir rapidement les méthodes de formation et d'entraînement. En effet, les exercices d'entraînement actuels et les architectures de CAX ne sont plus adaptés, puisqu'ils ne prennent pas en considération la valeur ajoutée apportée par les systèmes C4I. Ils ne permettent pas, par exemple, de stimuler le SIR avec des données appropriées pour le C4I. ESTHER, acronyme pour "Environnement Synthétique de THéâtre pour l'Entraînement des PC Régimentaires", est un Programme d'Etude Amont (PEA) piloté par la DGA. Il a pour objectif d'étudier la faisabilité de doter l'armée de terre d'une structure d'accueil de type plug-in permettant la connexion nationale et multinationale de C4I et de systèmes de simulation HLA distribués et offrant des services pour la préparation, l'exécution et l'analyse des exercices d'entraînement. Pour le PEA ESTHER, l'exigence primordiale de l'armée de terre consiste à faire communiquer entre eux les modèles de simulation existants et les C4I actuellement déployés, pour satisfaire ses besoins de formation et d'entraînement. ESTHER s'attache donc particulièrement à l'interopérabilité entre le SIR et JANUS HLA. Des résultats convaincants ont d'ores et déjà été obtenus dans le domaine de l'interopérabilité entre C4I et systèmes de simulation, abordé selon l'approche en deux étapes suivante :

- *La première étape concerne la configuration des systèmes de simulation et des C4I <u>avant</u> leur déploiement et leur utilisation. Cette étape comprend l'identification et la mise à disposition des données pertinentes à partager, permettant ainsi d'assurer **l'interopérabilité dite statique**. Dans le **domaine opérationnel**, les données statiques telles que l'ordre de bataille, la position initiale des unités et leurs ressources, les réseaux de communication tactique et les lignes de coordination doivent être identiques pour les deux types de systèmes. Dans le **domaine technique**, l'interopérabilité statique concerne la configuration du temps de référence, les adresses de messagerie des C4I, les adresses IP des systèmes informatiques, les fichiers de configuration des fédérés et des routeurs. Actuellement, les données statiques du domaine opérationnel sont disséminées entre les systèmes de simulation et les C4I, et l'initialisation de ces derniers implique un processus de distribution sélectif. Jusqu'à présent, les systèmes de simulation et les C4I ont été conçus selon des filières bien séparées. Leurs standards d'échange respectifs ne sont pas compatibles, ce qui impose la réplication manuelle de l'information d'un système à un autre. Ces opérations prennent du temps, consomment de la*

Paper presented at the MSG-022/SY-003 Conference on "C3I and M&S Interoperability", held in Antalya, Turkey, 9-10 October 2003, and published in RTO-MP-MSG-022.

ressource et introduisent des risques d'erreurs dues à de mauvaises interprétations. Des mécanismes doivent donc être mis en place pour automatiser la configuration commune des systèmes de simulation et des C4I.

- *La seconde étape concerne la connexion bidirectionnelle et la coordination entre systèmes de simulation et C4I durant l'exécution de la fédération, permettant ainsi d'assurer* ***l'interopérabilité dite dynamique****. Du point de vue* ***opérationnel****, cela signifie que les C4I doivent pouvoir émettre des ordres aux unités subordonnées (i.e. unités simulées) et recevoir en retour leurs comptes-rendus issus de l'environnement simulé (position des subordonnés, état des mines, données logistiques, …). Cela signifie également que les activités des deux systèmes doivent pouvoir être contrôlées et synchronisées. D'un point de vue* ***technique****, l'interopérabilité dynamique impose une compréhension commune du champ de bataille numérisé afin de disposer d'une information cohérente, et l'utilisation de standards d'échange identiques pour la communication de l'information entre ces systèmes. Le modèle de données des C4I et les modèles de données des systèmes de simulation (et de la fédération) doivent converger, ou au moins se recouvrir partiellement, faute de quoi l'interopérabilité n'est pas envisageable. Aujourd'hui, des passerelles sont utilisées pour traduire et mettre en correspondance l'information entre les systèmes. Cependant, ces passerelles sont conçues pour fonctionner dans un environnement déterminé et doivent en outre suivre les évolutions des C4I. C'est pourquoi au-delà de l'alignement des modèles de données, il semble indispensable pour l'avenir d'aligner également les architectures en partageant des modules communs.*

Ce "papier" présente dans le détail les difficultés introduites ci-dessus, il décrit les solutions telles qu'elles ont été implémentées dans ESTHER, puis il propose un aperçu des prochains travaux qui seront accomplis dans la suite du PEA dans le domaine de l'interopérabilité entre systèmes de simulation et C4I. La présentation s'achève avec une synthèse du retour d'expérience de l'exercice DEFTEMP conduit à l'EAI en mai 2003.

OVERVIEW

The newly fielded French Regimental Information System (SIR), covering both Battle group (Battalion Level) and Elementary units (Company Level), urgently requires an improvement to the current education and training methods. Previous training courses and CAX architectures are no longer suitable as they do not take into account the added value provided by C4I systems. They do not stimulate SIR with appropriate C4I data. ESTHER (Acronym for "Environnement Synthétique de THéâtre pour l'Entraînement des PC Régimentaire") is a French MoD R&T program. It is dedicated to exploring the feasibility of providing the French Army with a plug-in framework allowing national and nation-wide connections of distributed C4I and HLA Simulations and offering services to achieve preparation, execution and analysis of training courses. The highest priority Army requirement is for ESTHER to bridge the gap between the legacy Modelling and Simulation tools and fielded C4I systems to support Army education and training activities. Moreover, ESTHER addresses the interoperability between SIR and JANUS HLA. Beneficial results have been obtained in the area of M&S and C4I interoperability according to the two-stage approach below:

- *The first stage is the configuration of M&S and C4I systems prior to their deployment and common use. This stage covers the identification of the relevant, shared data and distribution. This is called* ***static interoperability****. In the* ***operational area, static data*** *like order of battle, terrain, initial units location & resources, tactical communication network and operational limits have to be consistent in both systems. In the* ***technical area****,* ***static data*** *covers the configuration of reference time, C4I Mail addresses, systems IP addresses, network masks, RTI (rid file) and routers. Currently, the operational static data are shared out between M&S and C4I systems and their initialisation imposes a selective distribution. Up to now, as M&S and C4I were developed along separate tracks, interchange* *standards are not compatible. This usually forces manual replication of information from one system to another. Those operations are time and resource consuming and introduce risks of errors due to wrong interpretation. Thus, mechanisms have to be developed to automate the common configuration of M&S and C4I systems with appropriate data.*

- *The second stage concerns the bi-directional connection and the co-ordination between M&S and C4I systems during the federation and C4I execution. This is called* ***dynamic interoperability****. From the* ***operational point of view****, it means providing the capability for C4I to send orders to its subordinate units (i.e. simulated units) and to receive reports from the M&S world (subordinates location, minefields status, logistic data etc.). It also means providing control and synchronisation of both systems activities. From the* ***technical perspective****, dynamic interoperability implies a common understanding of the digital battle space in order to handle the information consistently, and the use of the same interchange standard to carry the information between both systems. The C4I Data Model and the Simulation/Federation Object Model must converge, or at least partially overlap, otherwise no interoperability could take place. Currently, gateways are used to translate and map the information between systems. However, those systems are made to run in a limited environment and must cope with the improvements of the legacy C4I. That is why, beyond the alignment of data models, it appears mandatory in the future to align the architecture by sharing a common structure.*

The paper describes in more details the issues introduced above, depicts the current solutions implemented in ESTHER and gives an insight into the next ESTHER M&S and C4I interoperability studies. It concludes with the lessons learnt from the DEFTEMP Exercise held at EAI (Ecole d'Application de l'Infanterie) in May 2003.

1.0 INTRODUCTION – BACKGROUND

1.1 SIR overview

The SIR (Regimental Information system) is the French Army C4I covering both Battalion and Company levels. This information system equips Army Combat, Combat Support (Engineering and Artillery) and Combat Service Support (Logistics) units.

It is interconnected with the following French Army C4I systems :

- SICF (Communication & Information system of the forces) which operationally equips the Army Brigade and Division levels,
- the LECLERC information system already fielded,
- ATLAS (Automation of Fire and Connections of Ground-to-ground Artillery) which will replace in the short term the current system ATILA for the artillery chain,
- the future SIT (Terminal Information System) which will equip all the army units at section level in 2008.

The communication between the previous systems is based on the SICAT Army electronic message format and the XL message text format. Communication networks within the SIR are ensured through the PR4G (Radio Set 4th Generation).

The SIR is mainly installed in the VAB (Forward Armoured Vehicle) with a single or a double workstation configuration.

1.2 Training and Education with SIR

The newly fielded SIR requires an improvement to the current education and training methods for the personnel of the Command Post (CP). It is indeed necessary to take into account the added value of the system on the command process. Mentality will have to evolve to substitute data processing for the paper map to support the decision making process.

Du to the amount of information to be handled, it is not easy to create an attractive education course for the pupils. The first SIR education courses are relatively academic and theoretical, in order to give a good vision on the wide spectrum of the system. However, the SIR pupils key concerns are obviously the tactics, and it is difficult to demonstrate the SIR added value on the command process with a "static" or low interactive education course.

The SIR training issue is a stumbling block as this system is perceived by the users as a constraint due to the amount of information that have to be introduced during an engagement. CP officers are reluctant to use it because the system changes their current habits and seems to add workload.

Thus, both for education courses and training exercises purposes, it appears mandatory to propose to the SIR pupils or trainees a tactical environment as realistic as possible allowing the automatic "stimulation" of the SIR.

NB: the use of the SIR will probably never replace voice communications, particularly important and critical during the combat.

1.3 SIR Usability

The tasks to be achieved at CP level are schematically the following :

- Reception and processing of Operation Orders (OPO) and Fragmental Orders (FRAGO) from the superior,
- Generation and transmission of OPO and FRAGO to the subordinates,
- Generation of requests for information to the subordinates,
- Reception of the Reports from the subordinates,
- Update of the Operational Picture,
- Generation and transmission of the reports to the superior.

These tasks could be achieved more effectively with the use of the SIR. Are not software Copy and Paste the most common used functions as they help saving time ? Before reaching this point, it is necessary that the officers gain enough confidence in the system to decide to move from the paper maps to the computer.

1.4 SIR Stimulation objectives

The aim of the battlefield digitisation allowed by the C4I chain is to automatically feed each C4I system at any level with information coming from subordinate units, reducing the tiresome activities related to operational picture building and allowing each commanding level to concentrate on operational capabilities.

In the SIR training and education area, the stimulation allows to initialise the data flow, populating the C4I system at Company level with information from the synthetic forces in JANUS. The reduction of this tiresome activities previously devoted to the SIR pupils or trainees, allows them to focus on the operational capabilities (operational message system, operational picture management, and information management) Hence, they have more time available for tactical tasks (analyse the information, take decision and send appropriate orders). They can discover the added value of the C4I system, gain confidence and get convinced time after time to move from paper and manual tasks to computer.

This concept of stimulation implies to address the issue of C4I-Simulation interoperability detailed in

§2.0.

2.0 C4I-SIMULATION INTEROPERABILITY ISSUE

Various approaches were proposed to conceptualise the C4I-Simulation interoperability issues. The approach retained within ESTHER covers two stages:

- Static interoperability which deals with the configuration of both systems before execution,
- Dynamic interoperability, which deals with the bi-directional connection between the C4I and simulation systems and with their co-ordination, during run time.

This approach is presented below for C4I-Simulation interoperability in general, before being instantiated for the particular SIR & JANUS case in section 3.0.

2.1 Static interoperability

This stage consists in configuring the simulation and C4I systems before execution. Relevant (technical and operational) data have to be identified, shared and appropriately distributed to each system.

2.1.1 Data Identification

In the operational area, the initial configuration data shared and needed by C4I and simulation systems are as follows:

- **The Terrain**: It includes data relating to the theatre of operation. The availability of data bases is a first issue. However, it is much more a financial and calendar concern than a technical one. In fact, different sources and data formats are available as well as editors to modify such data. The consistency is a second issue. Terrain data must be consistent even if the aggregation level of the data handled by the two systems are different. As an example, elevation and planimetry must be the same whatever the systems so that the line of sight function provides consistent results.
- **The Order of Battle (ORBAT)**: This is the organisation of the fielded friendly and opposite forces, with different representations according to the C4I and simulation needs. On the C4I side, the representation must be compliant with the hierarchical organisation. In addition, the naming conventions and the operational symbolic are very important. The ORBAT may evolve during the engagement with possible reinforcements, and must be displayed with an aggregation level consistent with the CP level in the hierarchy. On the simulation side, the key point is to define an organisation allowing the creation of simulated units, their characterisation with physical, dynamic and behavioural models, their assignment to the simulation operators. If every forces and units must be defined on simulation side, it is not mandatory on C4I side. The discovery of unknown units may happen in real time and must be identified on case to case as single elements out of the conventional ORBAT.
- **Tactical information**: Initial information comes from the OPO: co-ordination lines, reports lines, forbidden areas etc. These data constitute guidelines which must be consistent between C4I and simulation systems in order to prevent misunderstanding between pupils/ trainees and subordinates managing simulation units. Initial information deals only with the friendly forces. Information relating to the opposite forces is an assumption of the enemy mission, strength or location. The consistency between C4I and simulation is required but not mandatory.
- **The initial situation**: This defines the initial location of friendly units, and their first stages of displacement. The accuracy of the location is not essential for C4I which usually displays aggregation of units, but is mandatory on the simulation side which must also include all the data describing the friendly and the opposite forces. Lastly, an initial planning of the displacements for the units can be defined before the beginning of the run, in order to speed up the exercise launching phase.
- **Initial Resources**: This part deals with Combat Service Support (human and material supplies as

food, ammunitions, fuel, etc). Initial resources must be consistent between C4I and simulation systems. From the C4I point of view, this information is managed inside logistics arrays to request supplies when the limit of the consumption is reached. On simulation side, these data are mandatory for the models and to generate relevant reports towards the C4I (See §2.2).

- **Tactical Communication Networks**: The realism of the tactical communication network is more and more requested from military personals for training purposes. Operational and physical characteristics of communication networks for data transmission must be taking into account. As an example, the organisation of the network with relay elements, range, frequencies and status of operational devices, the conditions of propagation, must be modelled. Units equipped with C4I systems have to be identified in the simulation. At the end, the simulation must shared with the C4I system the network topology, the users and operational addresses.
- **Mailing system**: Exchange of operational messages are usually performed via a mailing system. It is mandatory to share the operational user directory between C4I and simulation.

In the technical area, the initial configuration data shared and needed by C4I and simulation systems information are as follows:

- **Information networks**: The C4I network and the simulation network have their own configuration parameters. Most of the time, those parameters must be modified to allow communication between C4I and simulation systems: changes in IP addresses and masks, declaration of addresses (hosts file), declaration of the default gateway and routers. The technical configuration of C4I is made once for all when the system is delivered to the forces according to technical military guidance. Changing C4I parameters thus implies the reversibility and the flexibility of the system.
- **Space-time References**: C4I systems have their own time management and location means, based more commonly on GPS (Global Positioning System) and they work in real time (BRAVO, ZOULOU). On simulation side, the time is set up when the simulations are launched. In addition, the time could evolve differently than real time. In the case of a training exercise for instance, the exercise may go faster for pedagogic objectives. Then the C4I time is usually no longer suitable with the needs of the exercise. Now, as adequate temporal information is essential for the time stamping of operational messages, the C4I time has to be managed by simulation from the beginning of the education course or training exercise.

The identification of the SIR-JANUS static interoperability data is detailed in §3.3.1.

2.1.2 Distribution of the data

The technical and operational data having been identified in the previous section, it is necessary to make them available to both systems, C4I and simulation.

The data must be distributed to both systems, in accordance with the needs and specificity of each one:

- C4I are characterised by an organisation, hierarchical levels and manning,
- Simulations are characterised by simulated units (more or less aggregated) and associated resources (fuel, ammunition, personals).

C4I and simulation systems having been developed in very different manner, the semantic correspondence between them is not immediate: Hierarchy (Battalion, Company, etc) and Organisation (armoured, infantry, etc) are not consistent a priori. As an example, the Company can be called Battery or Squadron, according to the organisation concerned.

Under these conditions, manual transfer of information from one system to another is the obvious solution. However, it needs man power, it is time-consuming, and errors may occur due to wrong interpretation. In addition, for each modification in one system, it is necessary to check and make the corresponding modifications into the other systems.

To solve the previous issues, it is then easier to create mechanisms which will facilitate the common configuration of C4I and simulation systems for education and training purposes. Such a mechanism includes:

- the definition of one or several data interchange formats (DIF). This is already the case for terrain with SEDRIS. But SEDRIS is not used by the C4I community which prefers VMAP and DTED files format. Besides, SISO papers mentioned attempts for the definition of a DIF ORBAT, without any standards so far. However, interchange format are still missing for the transfer of tactical information as for instance operational overlays, initial forces situation and resources. The use of a standard language for the data exchange, as XML (Extented Mark up Langage) which is very flexible and easily readable with many freeware tools is a solution to recommend.
- the definition of rules (who provides what ?). C4I systems could be the provider for operational data.
- and, finally the organisation of exchanges when the overall information needed is completed. The creation of a conductor to collect, map, achieve the consistency of information before distribution is a solution to explore.

The mechanisms developed for distribution of data between SIR and JANUS through ESTHER are detailed in §3.3.2.

2.2 Dynamic interoperability

This second stage addresses the running of an education or training federation. It takes into account the bi-directional connection between C4I and simulation systems according to operational and technical point of view.

2.2.1 Operational issues

The aim is to allow the CP officers to use their C4I system in the most realistic and efficient manner. It means that the concept of stimulation explained in section 1.4 must be fully implemented as describes below:

- **Sending Orders** to the subordinates (i.e. to the simulated units). Two possibilities have to be considered. The first and easiest way is for the subordinate units to own a C4I same as or interoperable with the training audience's C4I. The second approach is at the simulation level to be able to extract from the OPO the most important elements to drive automatically simulation models. It means for the latter that the simulation can capture the operational message and knows how to decode the information. To deliver the message to the simulation side, the trainee must send it to a virtual C4I system (i.e. the simulation) referenced in the Mail user directory.
- **Sending Requests** for information to the subordinates. The approach is the same than above. However, the message processing could be more or less automated. As an example, if the request is to obtain the logistic status of the subordinate units, the answer could be sent automatically from the simulation. Again, it is mandatory to share the same Mail user directory.
- **Receiving subordinates reports**: it deals with the location of the subordinates units, their status and the status of the obstacles etc. Those messages may be sent automatically from simulation at fixed time as in real live. They may also be generated by the simulation operator when it is needed by the hierarchy.

Finally, the operational issue addresses the control and the synchronisation of both C4I and simulation systems. It mainly deals with the time as discussed in section 2.1.1. Thus, C4I must be managed by the federation as "time constraint" federate. Of course, C4I will never be time regulating. This last requirement is useful when exercise is frozen or must be restarted at a certain time.

2.2.2 Technical issues

From the technical point of view, the bi-directional interoperability must be considered as detailed below:

- **The Simulation-to-C4I connection**: the generation of messages toward the C4I is quite simple to perform for most of them. The process consists in capturing from the HLA flow the data necessary for C4I, assembling them according to the appropriate message format, and sending this message to the C4I according to the shared Mail user directory. However, the synthesis or the aggregation of the information to the higher level of command can be a more demanding task. Thus, algorithms must be the same in C4I and simulation systems to keep the operational consistency.
- **The C4I-to-Simulation connection**: the issue is really more complex. The operational message information must be extracted (order or request) and made understandable for simulation. For the OPO (which contents a lot of free text), the orders assignment to the simulated units constitute a major stumbling block. It requires operational expertise in order for the simulated units to execute the right mission.

For both type of connections, the interoperability implies a common understanding of the digital battle space in order to handle the information consistently, and the use of the same interchange standard to transfer the information between both systems. The C4I Data Model and the Simulation/Federation Object Model must converge, or at least partially overlap, otherwise no interoperability could be forecast. In fact, it means that the way to describe an operational object in both systems must be the same or must be close enough to be able to identify common attributes with same meaning. For interchange standard, it is recommended for the simulation to use the same mailing system than the C4I.

Currently, gateways are used to translate and map the information between C4I and simulation systems. Their use presents the following drawbacks:

- The semantic translation happens only for very structured simple messages. For more complex messages such as OPO, it would be mandatory to use special keywords in free text fields that could be recognised by the gateway.
- These gateways are designed to run with a list of systems. Whatever the interface improvements of one of these systems, the gateway must be adapted.

That is why, beyond the alignment of data models, it also appears mandatory in the future to align the architecture of C4I and simulation systems. In the meantime, the gateway approach seems an interesting palliative solution, on the one hand to ease C4I and simulation interoperability while no standards, common architecture and data models are defined, and on the other hand to help improving the C4I-Simulation interoperability requirements.

3.0 ESTHER

The main recommendations highlighted in section 2 come from the ESTHER R&T program. The proposed solutions to bridge the gap between C4I and Simulation systems were developed ant tested within ESTHER. The lessons learnt are detailed below, after a brief presentation of the main features of ESTHER.

3.1 ESTHER Overview

ESTHER "Environnent Synthétique de Théâtre pour l'entraînement des PC de Régiment" is a Research and Technology Program launched by the DGA (Délégation Générale pour l'Armement) in 2001.

ESTHER is a framework allowing the connection of live, virtual and constructive simulations and C4I systems. ESTHER provides services to configure, manage in real time and prepare after action review for education courses and training exercises. Data consistency, C4I-Simulation interoperability and RTI optimization for distributed connection are also studied and demonstrated within ESTHER.

The objectives of ESTHER are of two types:

- Operational objectives divided into:
  - Distributed training on several sites,
  - Reduction of the man power and the time required to conduct and configure education courses and training exercise,
  - Increase of the operational realism,
  - Remote pedagogy and distributed debriefing,
  - Training at home station.
- Technical objectives divided into:
  - Use of the French C4I system, SIR,
  - Development of HLA interfaces for JANUS and GESI simulations,
  - Simulation of operational data networks,
  - Automation of the C4I-simulation connection via SICAT and HLA,
  - Experimentation of a Federation (ESTHER FOM) where JANUS, GESI and SIR must run all together.

The ESTHER program is divided into three stages over 4 years. The two years first stage, ESTHER G1V1, is now completed with experimentations performed early 2003. The second stage, ESTHER G1V2 will be finalised in 2004. The last stage ESTHER G2 will address the full program objectives and will be tested during a real Battalion exercise in 2005.

3.2 ESTHER G1V1 Main Studies

ESTHER G1V1 studies addressed the following topics:

- The development of an HLA plug-in framework,
- The implementation of an HLA interface for JANUS, based on RAL.
  Note : RAL (RTI Abstraction Layer) is a tool suite developed by the ANPROS (French Navy Operational Research and Simulation Centre) including a FOM independent library used as a middleware between the RTI and the simulation code.
- The development of models for tactical data network,
- The realisation of an interoperability gateway between SIR and JANUS.

The scope of this document is limited to the explanation of this last item.

3.3 ESTHER G1V1 C4I-Simulation interop.

The ESTHER G1V1 interoperability studies between SIR and JANUS are detailed in the sections below according to the two-stage approach, static interoperability and dynamic interoperability.

3.3.1 Static interoperability data

The ***operational elements*** to configure both SIR and JANUS are generated from an ESTHER as a unique source. The information for systems configuration managed within ESTHER are detailed below.

The Terrain: a terrain editor was developed by the CROSAT (Army Operational Simulation & Research Centre) to generate JANUS terrain data base, from DTED and VMAP files. Thus, it is possible to generate any terrain needed for JANUS.

On the ESTHER side, the terrain is a RASTER map easily generated from USRP data, except for junction problems which require an extra cartographic tool suites.

On the SIR side, the RASTER map (re-used by ESTHER) is supplemented by DTED data.

Under these conditions, the terrain data base must be locally defined within each system. However, the name of the terrain is transmitted from ESTHER to JANUS in the "Terrain" section of an export file (see § 0). With this name, JANUS server and its clients are able to download the suitable terrain from JANUS data base. Currently, the terrain areas available in ESTHER are Mailly-le-Camp and the surroundings of Montpellier.

The Order of battle: A dedicated ESTHER editor is used to create the ORBAT which comply with the requirements of SIR and JANUS. Each node of the hierarchical structure is either a Force or a Unit. For Forces, attributes can be defined, such as name, colour, type (FRIENDLY, OPPOSITE, NEUTRAL). For each Unit, there is:

- a specific SIR section including: the level (Company, Platoon, etc), the type (PC or Unit), the organisation (Infantry, Cavalry, etc), the speciality (Anti-tank, etc), manning (Officers, NCO, Soldiers).
- a specific JANUS section where the following information must be specified: the type of platform, the logo, the percentage of initial ammunition and fuel allocation, etc.

An ORBAT library is available, which includes in particular, for the Friendly side, a French BattleGroup (GTIA) essentially made of armoured or infantry forces and for the Opposite Force, different formations corresponding to a standard enemy.

This ORBAT is transmitted to JANUS in the "ORBAT" section of an export file (see §3.3.2). This ESTHER exchange format is specific, as it was designed jointly with CAE to ensure compatibility with GESI.

Tactical information: A dedicated ESTHER editor is used to define operational overlays with main information including Assembly Areas (AA), co-ordination lines, reports lines. Exporting this information with the ORBAT is planned in the next ESTHER version.

Initial situation: A dedicated ESTHER editor is used to set the initial location of the simulated entities of the ORBAT (friendly and opposite forces) on the terrain; these positions will be exported to JANUS (see §3.3.2). JANUS initial planning (initial displacements) will be defined in the next ESTHER version.

Initial resources: The following information can be configured from ESTHER:

- The composition of the crews belongs to the ORBAT. This information is not processed by JANUS which only handles entities, but it is exported to SIR.
- The fuel and ammunition resources are defined in the ORBAT, expressed as a percentage of the initial allocation. This information is used by JANUS when the platform is generated. The default value is 100%.

Tactical communication networks: A dedicated ESTHER editor is used to create the different data communication networks, as the type of protocol to use. Each SIR officer defined in the ORBAT is seen as a network node.

The ***technical elements*** to configure both SIR and JANUS are generated from an ESTHER unique source as for the operational information. They are detailed hereafter:

Information networks: A dedicated ESTHER editor (the hardware configuration editor) is used to define information relating to ESTHER federation, which includes:

- Sites where hardware is deployed,
- Each hardware item characterised by a name, an IP address, a type, and a mask.

Depending on the type, additional information is entered:

- For SIR: SICAT address,
- For a JANUS client: its server,
- The network-type hardware (routers for multisite, Switch for single site).

The configuration for each hardware component is established in advance. This configuration task is inevitably manual.

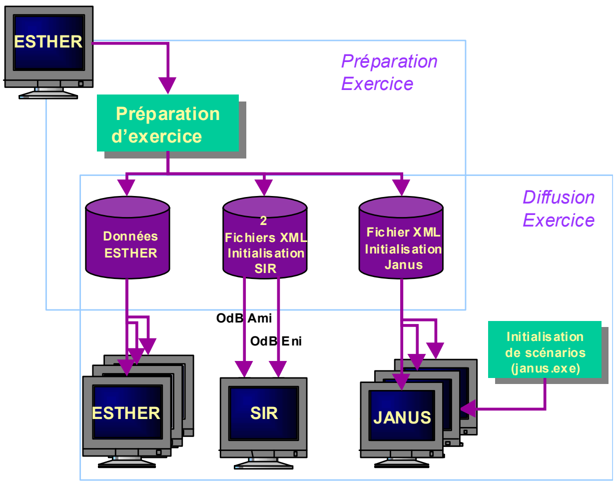
Mailing system: The subordinates of the SIR Battalion CP are SIR Companies. Each SIR must thus belong to the ORBAT and be linked to a platform. It must have an electronic SICAT mail address, and be declared in the SIR mail user directory. Each SIR being declared, it may send and receive messages in SICAT format (see § 3.3.3).

Space-time References: SIR is provided with a time and location reference based on the GPS. In the case of an education courses or a training exercise where the terrain and the time could be different than the real situation, the GPS is deactivated and the computer clock is configured with the exercise time in accordance with the federation time.

3.3.2 Static data distribution

When all the previous information are fully defined in ESTHER, they must be sent to the SIR and JANUS.

According to the approach described in §2.1.2, the distribution of data is handled via a third system. This is ESTHER which uses data interchange format and an exchange language, XML.



Static Distribution in ESTHER

The interchange format: As the format used by the SIR to export or import ORBAT is not a DIF format, the only concern is the export of ESTHER information towards JANUS and GESI. The ESTHER ORBAT being very precise for SIR requirements, the overall information is not required by simulations. As an example, the topics as Armoured, Infantry, Artillery, Engineering and Units sub-categories are not relevant for simulation. On the other hand, simulations need to know the exact platform name. Both JANUS and GESI servers dispatch the ORBAT entities between their clients. As these simulation systems own their file format to store the data, ESTHER can not comply with these two DIF and therefore will generate an XML file; each simulation being in charge of completing the translation.

The exchange language: The XML language is used to export the following information:

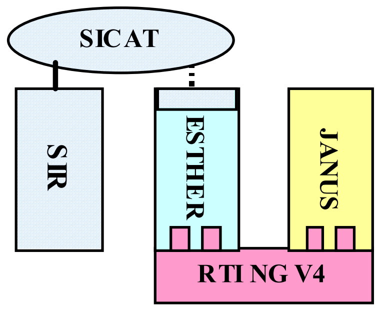
- SIR XML files: Two XML files are generated to describe the Friendly ORBAT, and Opposite ORBAT. They comply with the SIR import/export XML format;
- JANUS XML file: A third XML file is the JANUS and GESI export file which contains various sections describing:
  - ORBAT with the initial location for each platform,
  - the relations between forces (friendly and opposite),
  - the description for each simulation server of the names of its clients,
  - the dispatching of ORBAT units between simulation workstations,
  - the weather conditions,
  - the name of the terrain,
  - the time of the federation when starting the exercise,
  - the name of the federation and other HLA information.
- Distribution of the XML files: they are transmitted via FTP from ESTHER to simulations and SIR. For a multisite federation (planed for G2), the use of an ESTHER relay is foreseen.
- Processing of the XML files: The SIR XML file is processed according to the SIR ORBAT loading procedure. For JANUS, a manual processing procedure is started on each JANUS server for data import and insertion into the data base. This procedure is mandatory to convert the ESTHER ORBAT into the simulation files format (JANUS, but also GESI in next version).

Once this procedure executed, the education courses or the training exercise can be launched by ESTHER. Both ESTHER and JANUS are HLA federates in "regulating" and "constraint" mode. The "RAL Player Recorder" ESTHER federate (data logger) is in "constraint" mode only for the replay.

3.3.3 Dynamic Interoperability

Considering that the SIR is an operational system that can not be modified without restricted conditions and considering the workload already spent to develop a JANUS HLA interface without changing the overall architecture, it has been decided to take into account the dynamic interoperability between SIR and JANUS via a SIR-Simulation gateway integrated in ESTHER.

The picture below depicts the principles of JANUS-SIR coupling via ESTHER.



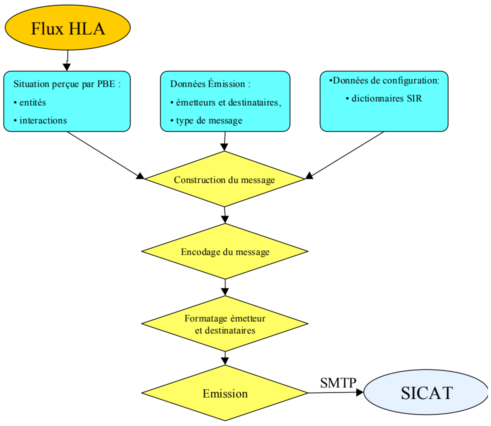
JANUS-SIR coupling via ESTHER

The capabilities of this gateway are presented below.

Gateway: It is a component of the ESTHER basic software and is based on a SIR piece of software This component is part of each ESTHER client. It makes it possible to create SIR messages from the information captured from the HLA simulation flow. In addition, this gateway stores every SICAT messages exchanged during the running of the federation.

Exchange format: The HLA objects and interactions are converted into SICAT messages for SIR.

Generation of messages: The process used to generate SICAT messages is depicted on the diagram below. It consists in extracting from the HLA flow the overall information, and encapsulating it into an appropriate SIR message selected by an ESTHER operator. The address for the final recipient is selected from the shared Mail User Directory. The message generated is finally sent via the SIR network according to the SMTP protocol.



SICAT message generation in ESTHER

SIR Operational messages: The messages being generated from ESTHER are listed below:

- Report messages from Company to Battalion:
  - SITREP/at a time: Periodic Friend and Opposite Situation Report at a time,
  - SITREP/PTSITU: Specific Friend and Opposite Situation Report,
  - CRRENS: Opposite Situation Report which belongs to the intelligence chain,
  - SITEFF: Situation Report on human resources,
  - SYNSAN: Medical Situation Report.
- Messages from Battalion to Company:
  - INFOSITREF, Friendly: Reference picture for Friendly Forces,
  - INFOSITREF, ENI: Reference picture for Opposite Forces,
  - INFOSITREF, Environ.: Reference picture for environment,
  - INFORENS: Reference picture for the intelligence chain.
- Messages on obstacles (bi-directional):
  - SITOBST REF.: Reference Situation for obstacles,
  - SITOBST MODIF.: Change of Status for obstacles.
- General messages:
  - ALARM and END/ALARM
  - GENTEXT: Free text message.

Message processing by SIR: The messages sent from ESTHER are processed by the SIR in the same way as native SIR messages. According to the SIR configuration and the types of messages, the different messages are processed automatically or not, and integrated automatically or not into the Consolidated Tactical Picture.

Operational co-ordination: ESTHER is designed to be the "master" of the federation. Thus, this principle is applied as follows:

- ESTHER starts and freezes the federation according to the following process: as every federates are time "regulating", freezing the federation means for ESTHER to never accept time advance grant.
- Considering the disconnection of the SIR GPS as described above, the SIR operates according to its own system clock which is not controlled by the federation.

With this version of ESTHER, the choice of the federation time is thus imposed by the SIR system time, which confers a certain rigidity to the whole system, preventing the capacity of freezing and restarting the exercise as wanted. For the next version, an operating system time management service will be integrated between the SIR and the federation.

3.4 Conclusion

The gateway between SIR and JANUS developed under the umbrella of ESTHER was used during the ESTHER G1V1 experiments which took place during the first quarter 2003 in the JANUS centers of the Army Infantry School (EAI) of Montpellier and of the Armoured School (EAABC) of Saumur.

The SIR Stimulation obtained via ESTHER was considered to be very interesting by the two schools for different applications. The EAI wished to use ESTHER for its DEFense TEMPoraire (DEFTEMP) annual exercise. The ESTHER experimentation to DEFTEMP is detailed hereafter.

4.0 INFANTRY DEFTEMP EXERCISE

4.1 Exercise principles

The "Defense Temporaire" (DEFTEMP) training exercise is held every year at the Infantry School in Montpellier. Following the ESTHER G1V1 experiment campaigns, the purpose to deploy ESTHER for the DEFTEMP exercise is to use the SIR / ESTHER / JANUS combination to generate an operational environment to train captains to command from their SIR embedded inside the VAB (Forward Armoured Vehicle).

Thus, the objectives are to:

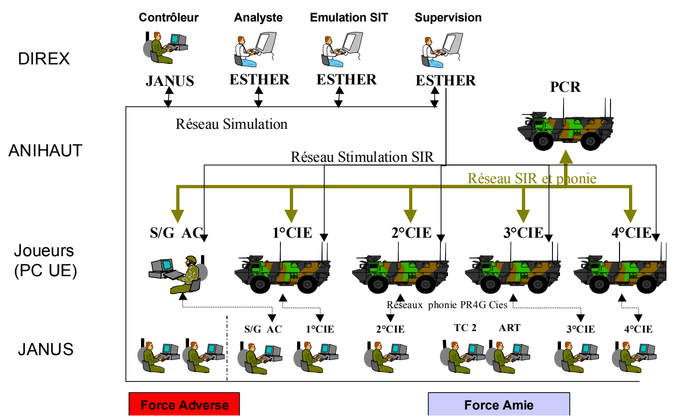
- Simulate the Terminal Information System (SIT), using SIR messages generated automatically from ESTHER,
- Reproduce a realistic SIR environment for the captain,
- Assess ESTHER limits with a complex JANUS exercise.

The main features of the exercise are as follows:

- The trainee group is made of 9 captains, with two captains per VAB and one captain on a SIR in a control room.
- The scenario is intended to oppose a defending Friendly force consisting of a mechanized Battalion, with its four Companies leaded by the trainees, to an attacking Opposite force made of two mechanized Battalions and one armoured tank Squadron.
- The whole forces amount to about 1,600 entities and the intended scenario duration is estimated to 5 hours.

4.2 Assets

The assets were deployed for both Forces according to the following diagram:



Exercise Organisation

- SIR: one SIR WS for the High controller at Battalion Level, and one SIR WS for each one of the 4 Company leaders in VAB
- JANUS: 1 JANUS server for Friendly and Opposite forces and 1 JANUS client for each Company,
- ESTHER: The server, 1 WS for EXCON, 1 WS for SIR Stimulation, 1 WS for real time Analysis et After Action Review,
- The SIR network between each SIR WS,
- The Simulation network between JANUS WS and ESTHER WS,
- The SIR Stimulation Network between ESTHER SIT emulation WS and the SIR WS,
- The Voice networks between SIR CPs and between JANUS operators and SIR CP.

Operational PR4G communication devices were deployed for its exercise to add realism.

4.3 Execution

The exercise was executed according to the planned objectives and program:

- A week was devoted to the technical building of the exercise; i.e. the configurations were set up for ESTHER (terrain and the exercise ORBAT), SIR, and JANUS. The week ended with a rehearsal of the exercise.
- During a second week, the exercise was executed and repeated several times, with the trainee captains changing roles: as Unit Leaders or Leader Deputies.
- At the end of the exercise period, a demonstration was presented to Infantry School (EAI) commanding general.

From a technical point of view, the organisation retained for ESTHER complied with the Infantry School requirements: the messages sent to the captains were generated by a single environment controller from the DISTAFF. The messages were handled as follows:

- Report Request by the captain to the section/platoon leader through the tactical voice communication system,
- Message generation request by the JANUS operator to the DISTAFF through the controller's voice

communication network.

The combination of three ESTHER, JANUS and SIR components for DEFTEMP exercise was a success. The lessons are detailed below.

4.4 Lessons learnt

Observing the captains' activities during the exercise made it clearly appear that voice communication and the map were preponderantly used by the Unit Leader. Most of the time, SIR was only used by deputy officers.

As the main explanation, the captains put forward that leading the engagement is a very heavy workload. They have a feeling that SIR represents an extra workload, since the information is not automated at the lower level. Entering information manually on SIR is considered as taking longer than on a paper map. Besides, the representation differences between the paper map and the electronic map have a penalizing effect.

This on-the-spot feeling expressed by the trainee captains was analysed by the School officers who made the following comments and correction :

- The SIT system will be deployed in 5 years time. The captain and their SIR will thus be the entry point of the digital battle space during this period.
- Using the paper map can be judged more effective at present, but:
  - the paper map can only be used by the captain, and is of no help for the higher echelon,
  - the C4I value added functions, for the terrain especially, are much effective than those provided by the paper map,
  - taking SIR in hand (training) will accelerate the process.
- So, it is necessary to make an effort to become quite familiar with SIR, and to acquire automatic gestures which will allow more time for tactical reflection.

In addition, the SIR and voice communication combination must be mastered. It clearly appears that using SIR must be considered as a three-phase process:

- **Initial deployment of forces**, where SIR is preponderant. It should be noted that the Battalion OPO must be "physically" presented by the Colonel to his Captains, with whom contact is essential so that the major effect intended can be correctly transmitted.
- **Leading the engagement**, where voice communication is preponderant, and where the automation allowed by SIR should provide a significant support to the Captain. During this phase, the captain seeks proximity with his Squad leaders to be aware in real time of any situation changes. In such conditions, the deputies can be in charge of the SIR, essentially to follow Friendly and Opposite forces locations, with a reporting to the Battalion.
- **Reorganisation at the end of the engagement**, where the SIR becomes again preponderant for a precise reporting to the Battalion, and transmission of logistic data.

This information relating to SIR being set forth, the SIR-Simulation connection via ESTHER is now analysed:

- As expected, stimulation through JANUS makes it possible to give the Captains a much more stimulating (even stressful) environment than the conventional in-room training environment.
- Because of their workloads, the Captains have not regularly made requests for reports. Moreover, the time necessary for consolidation to the Battalion, and then for distribution to the Companies (Friendly and ENI InfoSitRef messages) have resulted in sometimes important time-lags with respect to the

current situation provided by voice communication.

To motivate the Captains by giving them a regular and consistent stimulation, two corrective measures have been retained:

- **SIR Initial situation**: it must be defined during the initial phase, i.e. at the end of the reconnaissance phase performed by the squads, jointly between the Captains and the Squad Leaders in the captain's VAB,
- **SIR situation updating**: the following messages have to be sent as follows :
  - ➢ PTSITU messages must be regularly transmitted by default by the DISTAFF, for example every 30 minutes.
  - ➢ The Captain's PTSITU messages to the Battalion must be transmitted with the same periodicity, with a 10 minutes time shift.
  - ➢ The Battalion InfoSitRef message will follow the same logic.
  - ➢ The other messages, especially concerning obstacles, are transmitted as appropriate.

This very useful operational experience on the Captains' training, derived from the DEFTEMP exercise, will be used to improve the capacities of the next ESTHER version, more particularly from the SIR-Simulation coupling point of view. The outlines are described below.

5.0 WHAT IS NEXT

In accordance with the incremental logic of the project, the next version, ESTHER G1V2, will evolve according to the functions identified as necessary from the lessons learnt during the experiments and the DEFTEMP exercise.

5.1 New capabilities

Among the new functionalities (except the gateway), the following topics will be considered:

- **Multisite**: Practical application of study results, with the implementation of gateway federates,
- **New federate**: GESI simulation,
- **Logistics**: attrition of crews,
- **Simulation of communications**: on the basis of existing model in range, addition of the intervisibility aspect and of the electromagnetic propagation,
- **MMI**: Taking into account of new needs (aggregation, …).

5.2 C4I-Simulation Interoperability

In addition to the above-mentioned new functionalities, the SIR-Simulation interoperability topic will be improved on two axes:

- Improvement of connection,
- Introduction of SIR to JANUS connection.

5.2.1 JANUS to SIR improvement

As the existing linkage between JANUS and SIR was a success during the exercises, the operational lessons learnt led to precise specifications. These are, more particularly:

- Management of the federation time: the use of a time protocol should be considered to facilitate the overall federation time control by the DISTAFF,

- Implementation of new messages with, for example, new SICAT and/or XL messages, or the automatic generation of certain messages (PTSITU or CRPOSXL).

5.2.2 Introduction of Command Agents

Two kinds of Command Agents will de developed for ESTHER G1V2:

- Introduction of an ACE (ESTHER Command Agent) to simulate neighbours environment, with the purpose of decreasing the amount of personal required to perform this task. SIR messages will drive the JANUS Units representing neighbours environment,
- Introduction of an ACE for an automatic generation of messages after a request for information (Location, Logistic), with the purpose of simulating the SIT.

6.0 CONCLUSION

ESTHER is a R&T program contributing to propose C4I-Simulation interoperability solutions for current education courses and training exercises with special interest on JANUS and SIR. ESTHER addresses the interoperability between SIR and JANUS according to a two-stage approached. First the static interoperability which deals with the configuration of the two systems before execution, and second the dynamic interoperability, which deals with the bi-directional connection during the C4I and simulation systems running and with their co-ordination, during run time.

Under the umbrella of ESTHER G1V1, the connection from JANUS towards SIR was thoroughly addressed: The conditions of the interoperability were met with the identification and sharing of the needed data between both systems (static interoperability) and the most significant SICAT operational messages were built from the HLA simulation flow data (dynamic interoperability). Following successful experiments, the Army asked for ESTHER participation in the Infantry DEFTEMP exercise, whose operational range was tenfold increased by this realistic **stimulation** of the trainees via their SIR.

This very rich operational experience on the Captains' training will be used to improve the capabilities of the next ESTHER version, more particularly from the SIR-Simulation coupling point of view. For the next version, ESTHER G1V2, the JANUS to SIR connection will evolve, by taking into account new operational messages. Besides, the SIR to JANUS connection will be addressed as detailed below:

- Taking automatically into account the messages of requests for location/status reports from the Company to the Squads (position, manning, resources, …),
- Taking automatically into account of the neighbours environment by a Command Agent.

As for the previous version, experiments and a real Army exercise will provide and enrich the lessons learnt.

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SIMULATION FEDERATION IN COHERENCE WITH C3I AF ATC SYSTEM ON CAX PLATFORM

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Abstract

Modeling and Simulation at the Slovak Armed Forces has been since earlier 90's utilized to improve training, develop doctrine, tactics and materials, and improve combined and joint coordination. Recently the question of linking existing and future C3I systems with the Simulation Federation has emerged and is being reflected. The ability to develop a versatile modeling and simulation system in Slovakia linked with Air Force C3I ATC system, that can evolve with standards and tools is a big challenge.

An approach has recently been identified to meet this challenge through modular, open-architecture Training and Simulation Centers (TSC). The TSC provide a robust combined arms environment where tactics, equipment, and training development can be addressed. The TSC is capable of brigade, air wing and below level CAX exercises, and include pre-loaded scenarios with real world databases. The TSC are being enhanced through the addition of Virtual Full Mission Simulators training facilities, Digital Communications emulators, and with the links to the Air Force C3I system standard called "LETVIS", which is an important element of the Slovak C3I ASOC system. This interoperable vital concept was and is being successfully implemented at the Air Force Academy and appropriate C3I posts in Slovakia

The functional link and consistent communication standard between TSC and C3I system provides Slovak Armed Forces with the capability to train commanders, staff personnel, pilots, tank crew and cadets on developing tactics and standard procedures. Each configuration of CAX using C3I link feedback information has simulation tools, equipment, and capability for planning and executing operations interoperable with other DIS/HLA simulation and C3I nodes and operational facilities. This concept provides an expandable and flexible simulation, command and control environment suitable for training and the development of tactics and equipment, which significantly supports the process of Slovakia integration to NATO.

Current Capabilities

The Armed forces of the Slovak Republic (OSSR) currently have Modeling and Simulation capabilities and C3I Air Force ATC Systems capabilities at different locations. All these locations are very fast becoming very modern CAX platform training and exercise centers in the Central Europe.

The Air Force Academy located at Kosice (location of Training and Simulation Center (TSC)) provides a high – level general science and military academic program to all branches of the OSSR. As part of the instruction here, there are virtual simulators of Slovak Air Force operated light combat aircrafts used for individual pilot training, dog fighting training and flight training

The Military Academy at Liptovsky Mikulas (location of Training and Simulation Center (TSC)) provides a high – level general science and military academic program to all branches of the OSSR. As part of the instruction here, there are virtual simulators used for heavy vehicle driver training, and Anti-Aircraft (AA) gun training.

Another simulation is in a classroom where a large 3-D table – top terrain simulation board with approximately 1/48 - scale model tanks is used for maneuver training. Students radio C2 directions for these tanks, using R –123 and R – 173 radios, to an operator who moves the model tanks as directed.

Linked with above described training systems into the Simulation Federation is the C3I Air Force ATC system is called LETVIS. This system is a PC-based system consisting of several software applications that are used to monitor and evaluate the Slovak airspace situation. It provides air situation data display, radar data processing, and flight data processing. lt exchanges information via a LAN and a special-purpose leased WAN.

Additional C3I Air Force system, going to be linked is Air Sovereignty Operations Center (ASOC). The ASOC provides the capability to support airspace monitoring and command and control over mission execution ofair operations. It is a Sun Solaris-based system. Its initial capability allows the development and exchange of a national Recognized Air Picture (RAP). It currendy receives air situation and flight plan data from LETVIS system or in simulation mode generated data. It is intended to be used to conununicate with other ASOCs in the region, in accordance with bilateral/multilateral agreements.

The Slovak MoD supported in the year 2000 a Letter of Request (LOR) to US Army Simulation Training and Instrumentation Command (PEO STRI) for the Modular Semi – Automatic Forces (ModSAF) Brigade and Battalion level simulation. This training and exercise simulation creates and controls virtual battlespace entities that move, shoot, communicate, and react without excessive operator intervention.

ModSAF (now update OneSAF) is be hosted and operated on Linux machines by the Air Force Academy and Military Academy in Kosice and Liptovsky Mikulas. A training audience at the collocated Training and Simulation Centers, which trains and teaches military tactics and doctrine, and use the simulation for training at the Battalion and Brigade Commander and staff officer level and for use in training cadets at the Squadron and Wing operations level.

C3I Systems and CAX Platform

NATO nations are required to support a wide range of cooperative functions including combined training. Because it provides a cost-effective supplement to conventional training, CAX is gaining strong acceptance in NATO. While of growing importance, this requirement is in some background information is presented.

In 1992, SHAPE established an operational requirement for a NATO CAX capability. NATO clearly recognized the value of CAX in an environment of constrained funding, reductions in military force levels throughout NATO nations and environmental impact and resulting pressures from live exercises. A major tenet of NATO training is that CAX does not totally replace the need for live exercises, but does enable a reduction in the number and scope of exercises involving the deployment of troops. The value of CAX is particularly important in training senior level commanders and their staffs in executing complex operational orders involving multi-national force elements.

Although the requirement for a NATO CAX capability was established in 1992, the implementation of a NATO-owned CAX capability has been a slow and difficult process. Initially, NATO made use of simulation and modeling capabilities in the U. S. Warrior Preparation Center (WPC) at Ramstein Air Force Base in Germany. At present, both the WPC and the NC3A in The Hague, NL execute CAX programs.

NATO´s CAX capabilities are evolving and will continue to do so for several years. At the top command level, a candidate model is the U.S. Joint Theater Level Simulation (JTLS) model. This model is the one executed by both the WPC and the NC3A for NATO training purposes. There are also other models in use, including a Swedish theater level model used at the PfP Simulation Center.

For future CAX capabilities, SHAPE has formed a Multi-National Working Group which is formulating plans for a CAX program oriented toward the NATO Combined Joint Task Force concept in a multi-national environment.

NATO requires nations including Slovakia to have some initial capability to participate in training exercises. The primary focus of computer-assisted exercises will be on the conduct of operations and on the logistics support for national forces involved in such operations. Within those guidelines, however, nations may choose to implement whatever simulation models are appropriate to aid in meeting national training requirements. At some point in the future, it will become desirable or necessary to conduct computer-assisted simulations on a distributed basis, with several nations and NATO participating jointly. In preparation for such joint CAX activity, it is recommended that nations use models that are either identical to or substantially the same as those used by NATO. It is assumed that for such purposes, NATO will provide simulation models supporting training for multi-national coalition operations to all nations required to participate in NATO coalition computer-assisted exercises.

A requirement for conducting distributed simulations is the ability to exchange information between different models or between identical models executing at different locations. To enable this exchange of information, several nations in the SHAPE Multi-National Working Group mentioned above have been connecting several national simulations, which are currently integrated using the Aggregate Level Simulation Protocol (ALSP). ALSP includes a standardized structure for representing military force elements (e.g., tanks, aircraft, etc.) and for describing their operating parameters. The use of ALSP enables a specific simulation scenario (forces, equipment, fuel, logistics supplies, etc.) to be transferred between similar simulation models. In this manner, portions of an operational situation may be conducted by one participant (e.g., nation) in a distributed simulation and the results transferred to a different participant for other portions to be conducted. Results from the national distributed simulation experiments indicate that ALSP is useful but that the newer simulation integration standard called the High Level Architecture or HLA would be more effective. NATO has adopted HLA as the standard interface between new simulations, and plans for use of HLA are being developed in the Working Group.

Future requirements can be anticipated for interfacing a national CAX host computer with NATO CAX systems executing on CCIS servers. At present interoperability between national and NATO CCIS systems will require remote NATO CCIS terminals in national HQ locations. NATO presently requires isolation of NATO CCIS terminals from national CCIS computer terminals by "air-gap" interfaces. Eventually, security Guards, developed and approved for specific applications, will enable national and NATO CCIS systems to be physically interconnected. Once satisfactory Guard devices are available and implemented, it may be possible to interface CAX models with national and NATO CCIS systems.

The major operational functions supported by CAX are:

- Air operations and training
- Land operations and training
- Movement planning and coordination

The system components of Slovakia/NATO CAX interconnection are illustrated in Figure 1. The interconnection will be similar for Slovakia participation in a NATO-hosted CAX or NATO participation in a Slovakia-hosted national CAX.

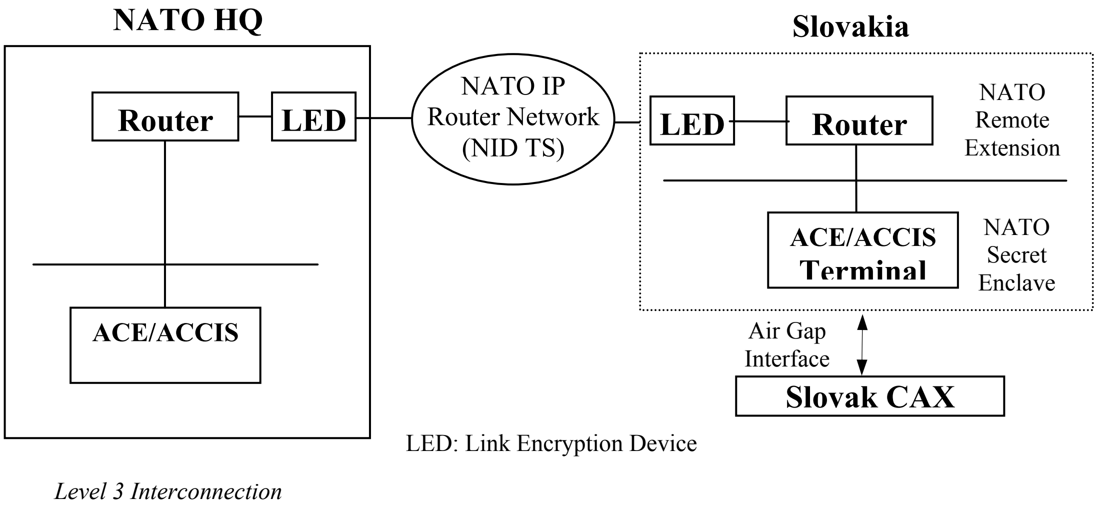

Figure 1. CAX: System Components-Near Term

After Slovak membership in the year 2004, it is likely that NATO would extend the NATO IP router into Slovakia and install capabilities for Slovakia to support classified email exchanges with NATO subscribers. Provision of an ACE ACCIS terminal would give Slovakia an initial connectivity with NATO CAX information.

It is expected that Slovakia operates its own CAX capability separately from NATO using an air gap interface. This is NATO Level 3 interconnection between systems.

In the far term, it would be possible to migrate to a configuration where a Slovak CAX system could be connected to NATO systems through an approved Guard to achieve NATO Level 4 interconnection, as shown in Figure 2.

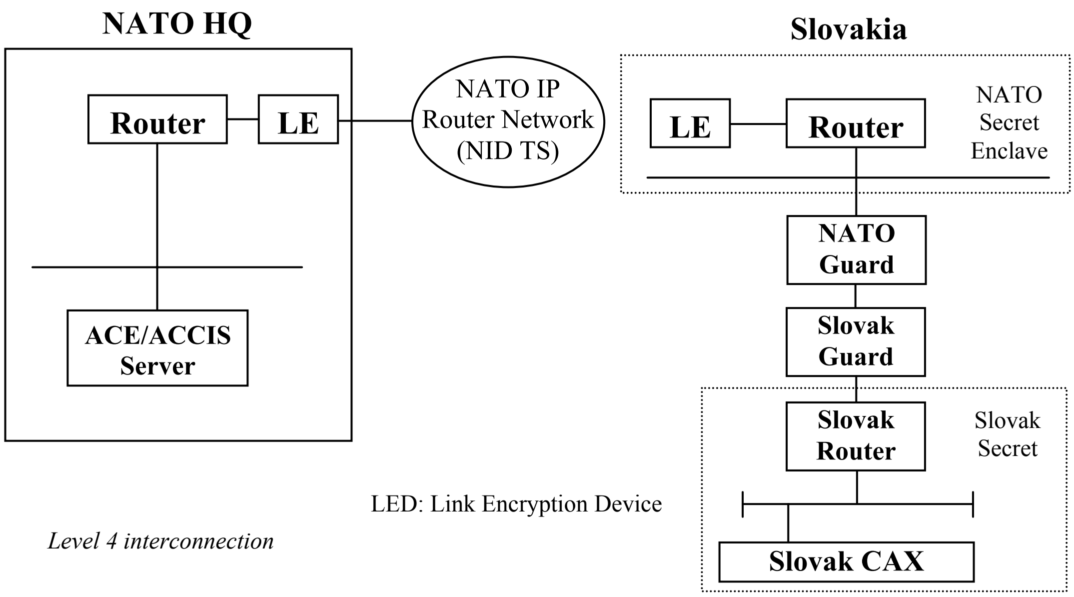

Figure 2. CAX: System Components-Far Term

Simulation Federation and Pre-NATO Accession

In the period before NATO accession, Slovakia already have developed its capability to engage in internal (domestic) CAX. The first step in this was to acquire or develop the necessary hardware and software. Computer models are in accordance with NATO standards wherever possible. Slovakia requested releasable interface standards through US FMS program and coordination cell. The initial goal was providing this training capability to the Slovak restructured Armed Forces earmarked for participation in NATO activities. Interfaces into domestic C3I systems drive design considerations.

The OS SR is currently reviewing the use of both C3I systems LETVIS and the ASOC; there may be possible cost savings if only one system used. However, there are more than 300 LETVIS workstations located throughout the OS SR. LETVIS will also be used as hackup for the civil ATC system and training within Simulation Federation. LETVIS processes radar data, tracks, flight plans, and wealher information in reality or for training purpose fictive, simulated inputs and it transmits tracks and flight plans to the ASOC.

The ASOC is located at the Combat Command Center. It is currently used only for training and testing. There are plans to transition to an eight-hour/day operation if additional positions can be funded in the new year. The ASOC provides the capability to process radar data, tracks and flight plans. The OS SR plants lo use the ASOC for exchange of information with regional ASOCs (in accordance with bilateral and/or multilateral agreements). The ASOC has also a link capability.

Given the LETVlS system current widespread deployment and capability, the OS SR will continue to use LETVIS as the primary air surveillance system. The ASOC will be retained and maintained for information-sharing with regional ASOCs/NATO systems. By doing so, the technical capabilily is retained to exchange information with similar systems once the necessary political agreements are arranged. In order to fully support future information sharing with neighboring countries, the OS SR should operate the link between the ASOC and LETVIS as a two-way link. An added benefit is that the ASOC has western-style air defense C3I attributes that can be used for training in simulated environment for coalition deployments.

OSSR also participates in the SHAPE/NATO C3 Agency "Cooperative Automation" and other seminars to familiarize PfP nations with CAX capabilities. Additionally, OSSR participate in PfP Simulation Network (PSN) exercises. The PfP training center in Sweden will host a distributed war gaming exercise facility. These exercises are expected to be open to participation by both NATO members and PfP nations including Slovakia.

In order to execute NATO and national simulation models, nations are required to provide adequate computer facilities. Specific requirements for computer systems are coordinated with SHAPE. However, in general, high end Pentium PCs and/or HP with extensive RAM and hard drive capacities are in operation. It may be necessary to use UNIX machines in some cases.

Post-NATO Accession

After NATO accession, Slovakia also will need capability to participate in NATO war gaming exercises for units down to the brigade level. Initially, this capability will consist of a remote terminal to provide an extension of the NATO CCIS system (ACE/ACCIS). This will represent a level 3 (air gap) interconnection with NATO systems. At some point in the far term, an interface between NATO and Slovak systems may be implemented as security permits.

In today's world of decreasing sizes of military forces, countries are relying on information as a significant force multiplier. Key to this concept is the use of automated systems to process and exchange information. As discussed above, the OS SR has few C3 Information systems currently in operation, particularly systems that support the automatic exchange of information. The OS SR is planning to develop new C3 information systems and to integrate them with existing training simulation tools in a Global Information System (GLOBIS) architecture. The GLOBIS architecture will incorporate and interconnect information systems from many areas within the OSSR.

Slovakia will also continue to implement, through acquisition or internal development, the capability to participate in distributed, NATO-led Computer Assisted Exercises. The initial capability should be designed to support internal requirements. This means that concentration will be given to providing interfaces to internal (domestic) systems. In addition to the obvious benefits derived from any training capability, this will provide Slovak officers the classroom for developing experience with CAX techniques.

Slovakia was provided with tactical level of CAX training model as ModSAF (OTB) but is this period should obtain an operational level command CAX training model as Joint Theater Level Simulation (JTLS), WarSIM, JSIM or NASM models.

The following requirements checklist will assist the OSSR in evaluating its Simulation Federation development program.

- Has the nation requested CAX software and training from NATO?
- Has the nation participated in, or is the nation prepared to participate in, the Cooperative Automation seminars given annually by SHAPE/NC3A?
- Does the nation currently use some form of simulation model to provide CAX training for national command and logistics operations?
- Are the nation's contributed forces equipped with suitable computer systems for the purpose of executing distributed CAX simulation models on national and NATO CIS systems and exchanging results in a near real-time mode?

Promising vision

In conclusion, only very efficient professional Slovak Armed Forces and stabile democratic political environment create the best platform for establishment of the Simulation Federation within integration of now existing or in future considered C3I ATC Systems in the frame of NATO membership under real promising vision to become a valid, credible NATO partner and member.

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A GRAPHICAL INTERFACE AND A DATA FILTERING SCHEME FOR JOINT THEATER LEVEL SIMULATION

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SUMMARY

Joint Theater Level Simulation (JTLS) [6-12] is the constructive simulation used to support joint/combined exercises at operational and higher levels in Turkish Armed Forces. However, JTLS does not fit all the requirements in these exercises. The tactical considerations may sometimes have a major impact on the decisions at higher levels. Especially, the resolution of terrain data does not allow simulating the required tactical details in JTLS. Moreover, participants of an exercise should interact with a simulation by using either real or realistic C2 systems. The standard user interfaces of JTLS, namely GIAC [1-5], MPP and IMT, cannot emulate these C2 systems in most of the cases. During the game, all the participants that use standard JTLS interfaces have the same perception of the operational picture if they are at the same side. This is not very realistic. JTLS cannot provide multiple perceptions for the same side. HOGAY is a generic graphical interface and filtering system developed to minimize these weaknesses of JTLS. In this paper we introduce the architecture of HOGAY, and the method to propagate data in HOGAY.

1.0 INTRODUCTION

Unless the constructive simulations are supported by appropriate user interfaces, they cannot fulfill the basic requirements, e.g., better immersion, being realistic, etc., of a computer aided exercise (CAX). If a realistic perception of the common operational picture cannot be provided to the users based on their side, level in the command hierarchy, communications tools and environment, the users cannot be satisfied even if the most complex and realistic combat models are used to calculate the attrition and mobility of units. Therefore, user interfaces are at least as important as combat models in military constructive simulations.

Joint theater level simulation (JTLS) has some shortcomings in this respect. In JTLS every terminal that belongs to the same side has the same view for the common operational picture. Every terminal of the same side learns about a unit as soon as any sensor of that side detects it. When the detection is fused, all the details related to the detected unit become available for the detecting side. This can make unrealistic impacts on the results of an exercise. A submarine commander can engage a surface ship more than 100 km away as soon as it is detected by a patrol boat, which does not have any link system. The graphical wargame interface application introduced, HOGAY, has been developed to overcome these difficulties caused by the user interfaces used in JTLS.

There are four factors affecting the design of HOGAY:

i) Requests of users: Players prefer to interact with JTLS using GUIs (Graphical User Interfaces) similar to real C2 systems. Requirements may change depending on the service that the player belongs to.

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ii) Interaction with JTLS by using a single program: Currently, the player interact with JTLS by using four programs, namely GIAC (Graphical Interface Aggregate Control), MPP (Message Processor Program), IMT (Information Management Tool), and OPM (Online Player Manuel). The interface program developed will perform the functions of all these programs.

iii) Visualization of detection/fusion information with a propagation delay: Currently, detection/fusion information is obtained instantly by all the players of the detecting side. However, this information should propagate with respect to the delay parameters between unit pairs. Moreover, it should also be possible to form links among some units. Information obtained by a linked unit is immediately passed to the other units under the same link without considering physical distance among them.

iv) A list of utilities prepared by the users of the other interfaces is also taken into consideration.

The paper is organized as follows: In Section 2, the system architecture of HOGAY is explained. Section 3 introduces Model Client Interface, and basic processes implemented. Propagation of information and filtering is detailed in Section 4. Section 5 introduces Player and Controller Interfaces. Finally, Section 6 concludes the paper.

2.0 GENERAL ARCHITECTURE OF HOGAY

There are three basic units forming HOGAY, namely Player Interface (PI), Controller Interface (CI), and Model-Client Interface (MCI). There is a dedicated MCI for the players of each side. These are names as *MCI-PI-violet*, *MCI-PI-orange*, etc. Moreover, there is an MCI for the controllers called *MCI-CI*. Players use PIs to interact with JTLS. CI is a PI with some privileges. It can fetch data for all sides and send some special administrative orders to JTLS and MCI. MCI is an interface between JTLS and end-users (players and the controller). PIs and CIs work on the Windows environment. They are developed by using Visual C++ and Delphi. MCI is implemented on Unix by using the C programming language.

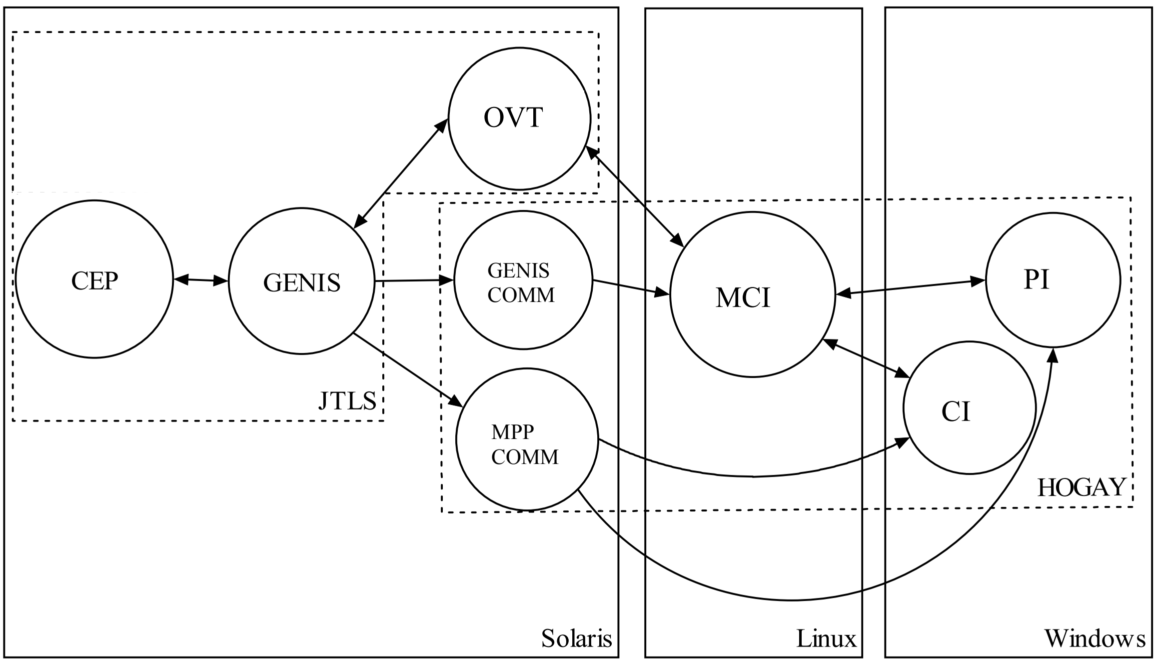

Figure 1: System Architecture

HOGAY has two more components also developed in UNIX environment by using the C programming language: GENIS-COM and MPP-COM. These components are included in the system design to improve the interoperability and reusability of HOGAY. MCI, PI and CI are independent from JTLS and other military simulation systems. These components use an application layer protocol designed for HOGAY to communicate. GENIS-COM and MPP-COM also use the same protocol to communicate with MCI and/or CIs and PIs. On the other hand, GENIS-COM and MPP-COM uses standard GENIS libraries to pass messages to or from GENIS. Therefore, adapting HOGAY to the version changes in JTLS is only limited to modifying GENIS-COM and MPP-COM which are also HLA compliant.

3.0 MODEL CLIENT INTERFACE (MCI)

MCI is a parallel processing program responsible from transmitting the GENIS data to PI-CI modules and the PI-CI orders to GENIS. There is a dedicated MCI for the players of each side. The MCI of a given side downloads the data specific to its side. *MCI-CI* downloads data for all sides and presents this data without any delay. *MCI-CI* also modifies the delay information related to the propagation of information among units based on the orders given by the controllers.

The MCI software consists of three fundamental processes and two supplementary processes for each new client connection, as shown in Figure 2. The fundamental processes are the *Main*, *Genis_Comm Reader* and *Updater* processes. *Main* does the elementary operations and initiates the required processes for each new client connection. *Genis_Comm Reader* is the process responsible of listening the GENIS socket and storing the incoming data. *Updater* updates the MCI data to be send to PI/CI modules. *Main* creates two new processes *PI_reader* and *PI_writer* for each new client connection. *PI_reader* receives the orders coming from the interface modules PI/CI and sends them to OVT. *PI_writer* sends the MCI data to the related interface module.

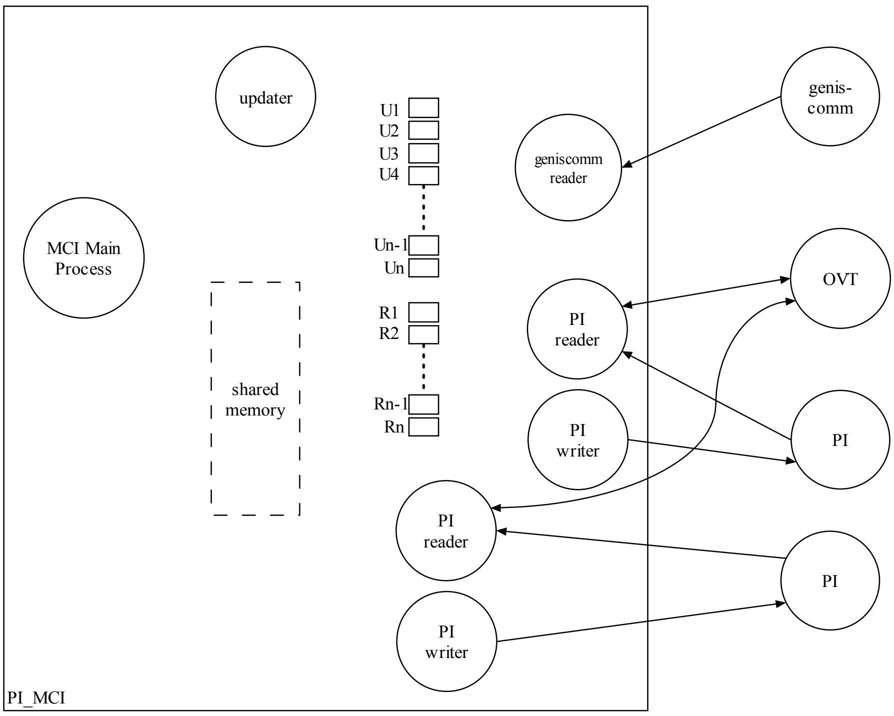

Figure 2: MCI Process Architecture

4.0 PROPAGATION OF INFORMATION

One of the most important contributions of HOGAY is the filtering module implemented in MCI and PIs. To pace with the changes in the game, its implementation is distributed between these two modules. Here a sample scenario, shown in Figure 3, is given to describe the filtering operation. In this sample scenario there are three players named O1, O2 and O3. Players are thought of as virtual units with zero delay values to the units under their authority. In this scenario, O1 and O2 have two units under their command and O3 has one unit under his command. Units are named B1 to B5.Delays between units are defined as GXY. (Here X and Y represent unit indexes.) For example delay between B1 and B3 is defined as G13.There are two relationships:

- Player-Unit Relationship
- Unit-Unit Relationship

A player can have more than a single unit under his/her control. For example player O1 controls units B1 and B2. Detections that reach to these units or the detections made by these units should be visible without any delay in the PI of O1. On the other hand, the other units can learn the detections made by units after a delay based on some parameters such as the position of units in the command hierarchy, the communications capabilities, jamming, links, and the distance between units. Delays between units are kept in a dynamic database. Delay values can be changed by the controller during the game.

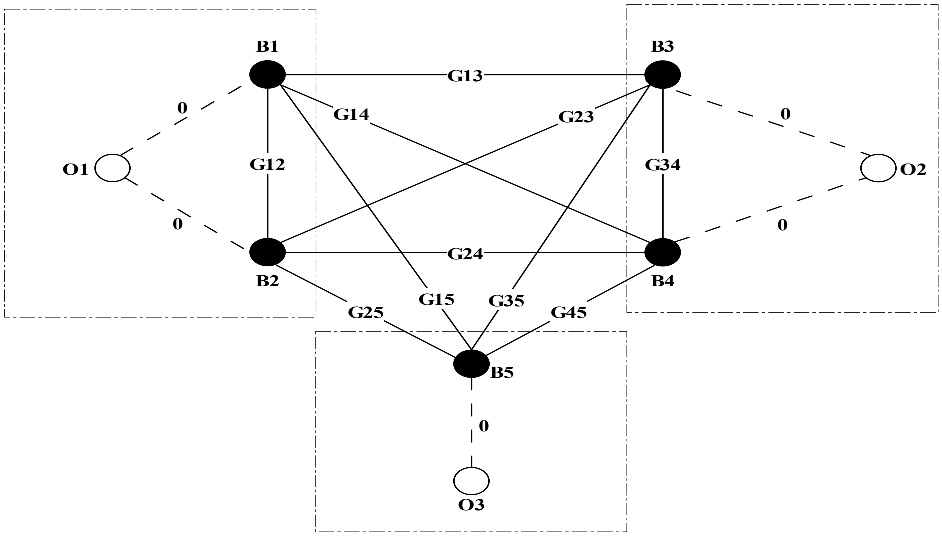

Figure 3: Sample Scenario

When MCI is run for the first time, or when the unit-to-unit or player-to-unit relations are changed, the shortest delay path between the units and players are calculated by using Floyd's all pair shortest path algorithm, and the results are kept in a matrix called *Floyd-Matrix*. Since Floyd's algorithm is a time consuming one, $O(N^3)$, it is assumed that the matrix is symmetrical, i.e. GXY is equal to GYX. When a PI connects to an MCI, the row related to the player of the PI from *Floyd-Matrix* is downloaded to the PI. This delay information, which gives the delay between any unit in the simulation and the player, is updated every time when the related row in the delay matrix in MCI is modified.

PIs do not reflect every update to the player as soon as they receive it from MCI. First they determine how long does it take to convey this update to the player based on the delay values. PI finds out the source unit of the update. If it is an update about a friend unit, that friendly unit is the source. However, when this is a detection data, or an update about an enemy unit, PI needs to find the detecting unit. In HOGAY this is done by checking the location of the detected data against the ranges of open sensors available in the friend forces. The closest owner unit of one of these sensors that can make the detection is accepted as the source unit. After this point it is only a lookup in the delay relations data, which is determined by related row of *Floyd-matrix* to find out the required delay for the update in the operational picture of the unit. The updates are inserted into a linked list based on their update time determined by using these delays, and made available to the player as their time come.

Filtering can also be bypassed, i.e. when an information update of a friend or enemy unit has arrived, it is shown on the player's screen directly without any delay.

5.0 PLAYER/CONTROLLER INTERFACE

PI is the interface unit that displays the propagated simulation data downloaded from MCI via TCP/IP. PI is the integrated form of GIAC, IMT, MPP, OPM. It includes all the options of these programs and more. Architecture of PI is composed of four DLLs and the main graphical interface program, as in Figure 4.

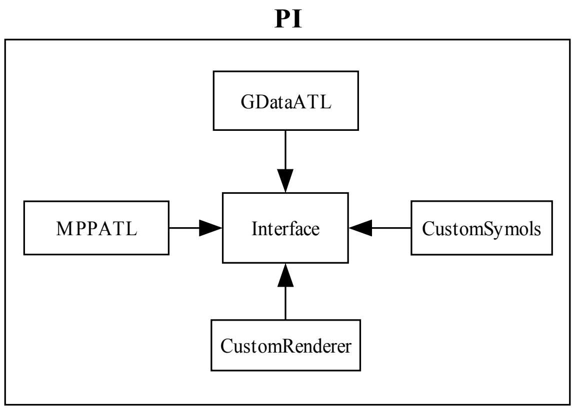

Figure 4: Architecture of Player Interface

GDataATL is a COM DLL implemented by using Visual C++. This module connects to MCI to download the simulation data and stores the updated version of simulation data. The filtered data is fired to graphical interface when triggered with time packets. Communication architecture of *GDataATL* is given in Figure 5.

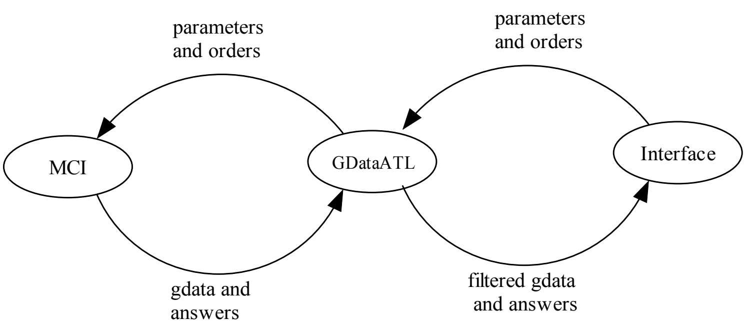

Figure 5: Communication Architecture of *GDataATL*

MPPATL is also a COM DLL implemented by using Visual C++. MPPATL connects to MPP-COM and fires the incoming messages to the graphical interface. *CustomSymbols* is a COM DLL designed for drawing the unit symbols in the graphical interface. This module is also implemented by using Visual C++. *CustomRenderer* is also a COM DLL implemented by using Visual Basic. *CustomRenderer* is used to draw user and unit lines, save or load them in layers.

Graphical Interface is the basic interface developed in Delphi. In Figure 6, PI and GIAC screens are shown. At the first glance, both of them are quite similar. The main difference is that PI uses raster maps while GIAC uses hexagonal maps. Apart from this, all the information panes, buttons, and windows are collocated in a dockable window in PI. This window can be dragged into any place, resized or minimized as needed. The order menus and the other menus are also positioned as in a standard windows application. Hence, it is easier to train the operators which are used to working in MS Windows environment.

PI has all of the utilities available in GIAC e.g., unit and user lines, display options, filtering options, panning, zooming, etc. Apart from them, it has some additional tools designed based on the lesson learned from the previous exercises. For example, three C2 systems, namely ICC, STACOS and a new C2 system, are implemented in PI. User selects one of them, and the screen looks like the screen of the selected C2 system. This does not change the tool bar or the menu but only the operational picture is shown in a screen that looks like the screen of the selected C2 system. Another important new tool is Local Tracks which are virtual units created by players to demonstrate probable units at that location. Local tracks can be created, deleted, moved or shared with other players. This new utility will be very useful in the detection/fusion steps or in electronic war models.

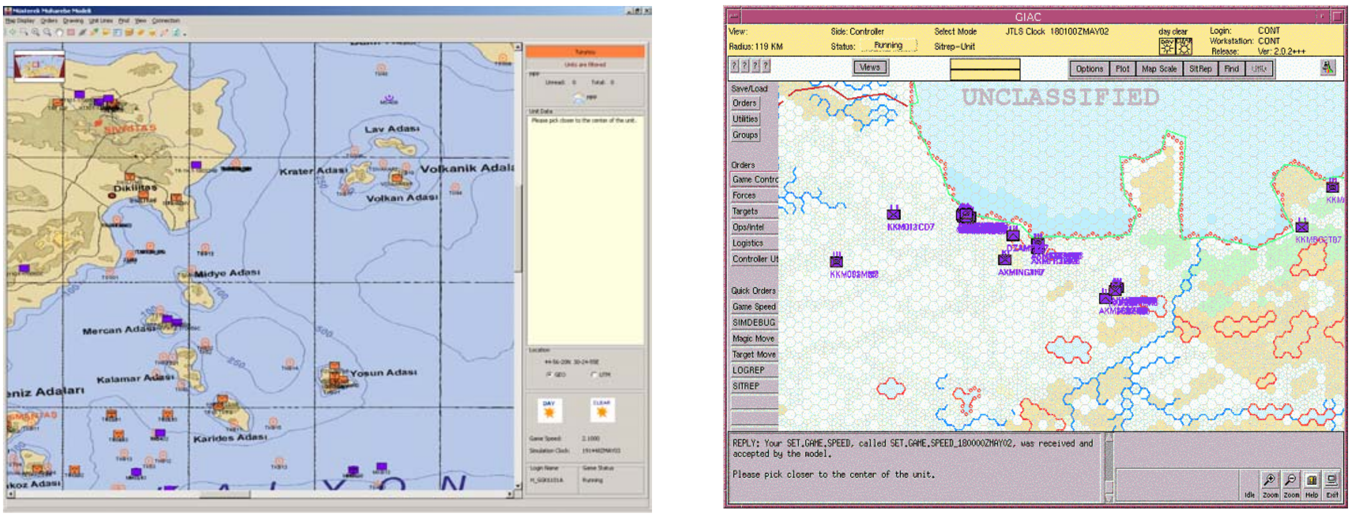

Figure 6: PI and GIAC Screens

The navigation on the map is also easier in PI where the location of the current screen in overall theatre is also shown in a navigation window. It is also possible to find out the length of a river or road as shown in the dockable information window in Figure 7. Another important tool available in PI is a very realistic three-dimensional (3D) flight simulator. Some screens from this real time flight simulator are shown in Figure 8. These screens are generated by using standard DTED formatted digital maps, satellite pictures and some additional data related to terrain features and textures.

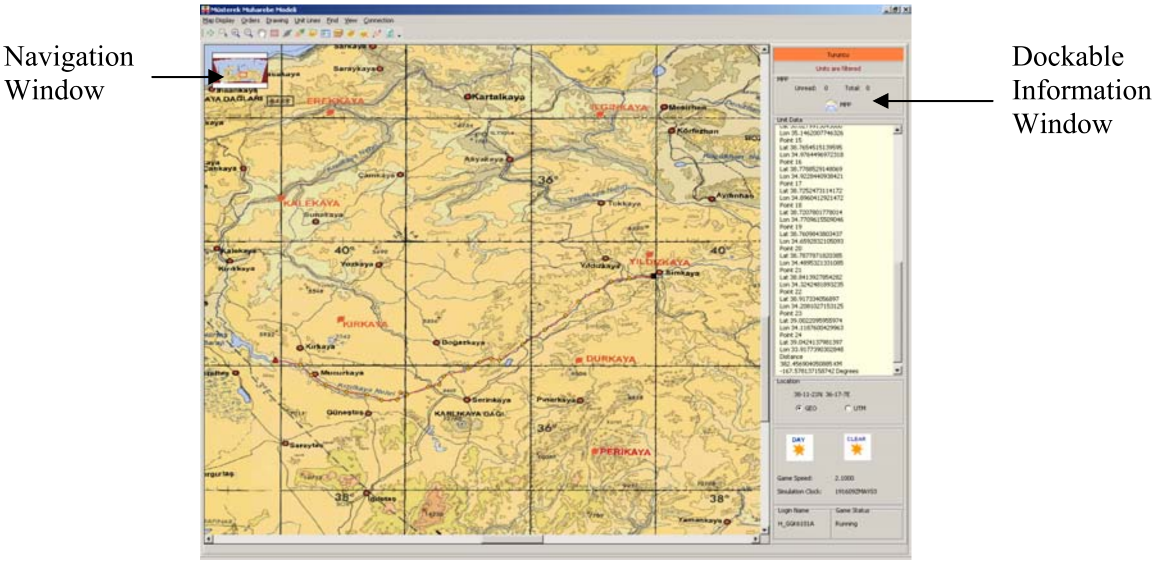

Figure 7: PI Utilities

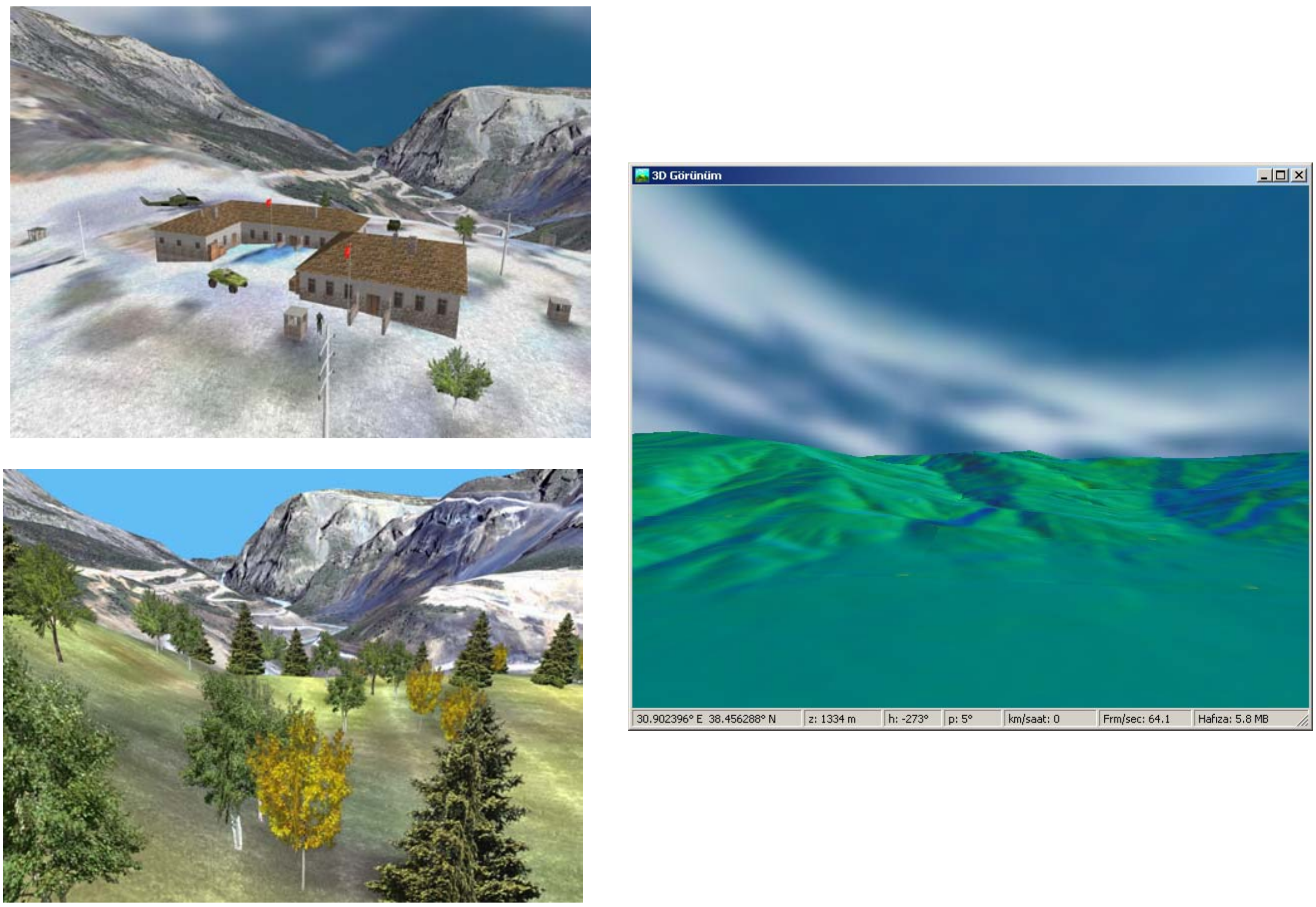

Figure 8: The Screens from the 3D Flight Simulator of PI

PI also presents a window where the information about the units and other assets in the theatre in tabular form. This tool, which is an enhanced version of IMT used in standard JTLS configuration. Another tool is the equivalent of MPP in JTLS where the users can see the messages generated by JTLS for them. Users send their orders to JTLS also by using templates similar to the ones in JTLS. With all of these utilities HOGAY will become the standard user interface for the constructive simulation systems used in Turkish Armed Forces.

CI and PI are the same programs. During the authentication stage order menus are dynamically created according to the user's type. So the only visual difference is the orders they can give. CI is connected to *MCI-CI* to get the whole simulation data without filtering in *GDataATL* if the user is logged as a controller.

6.0 CONCLUSIONS

HOGAY is an interface system which can connect to JTLS, and provide users with filtered perceptions based on command hierarchy and propagation delay. Available C2 systems in the Turkish Armed Forces are also emulated in HOGAY. Hence, exercise participants are better immersed into situation, and more realistic joint exercises can be conducted. HOGAY has also many new utilities which makes the players learn how to use it easier and operate it more effective. It was first used in a major exercise in 2003.

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Integrated Army Modelling and Simulation Data Network

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SUMMARY

The concept of a future Modelling and Simulation Network is based on a methodology of knowledge and information management. In the framework of this methodology the Integrated Army M&S Data Network will be established as an operational and technical concept to allow knowledge transfer between operational headquarters, study facilities, procurement agencies and training installations.

The Concept of the Integrated Army M&S Data Network has the following objectives:

- *Efficient data acquisition, processing and administration for a Modelling and Simulation environment,*
- *Data exchange between simulation systems and possible data sources (other simulation systems, C4I-systems, databases, etc.) based on a common information language,*
- *Installation of a common data management process to define, establish and administer a common information language*

The represented results reflect a series of substantial studies conducted by civil contractors. Special thanks go to Dr. Stefan Krusche, Mr. Peter Arwanitis and Mr. Ralf Pfrogner, IABG GmbH, Munich for their outstanding work on this subject.

1 MODELLING AND SIMULATION INFORMATION DOMAIN

1.1 Situation

Modelling and Simulation (M&S) is the generic term for operations research methods, the application of simulation in training and exercises as well as the simulation technology. M&S includes the provision and use of methods, models, scenarios and data in the areas of

- analysis and planning
- training and exercises
- research, technology and acquisition as well as
- support to military operations.

The goals, based on the conceptual Army Guidelines, are:

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- optimisation and comprehensive development approach over the application areas,
- linkage with the Army IT System, especially with the functional and command and control systems,
- modular driven architecture in the framework of an integrated system of models and methods,
- in-time provision of the best available and usable data.

One of the unconditional key aspects of the Concept of the Integrated System of Systems M&S is the realisation of a corporated Information Management.

Nowadays the existing legacy systems are tailored to the requirements of the relevant application domains. Systems developers use their own individual concept of information representation. Often these information concepts are inadequately documented, hidden in the program code or in the graphic user interface. Therefore the customisation and integration of legacy systems in a system of systems is either technically impossible, economically not acceptable or at a semantic and pragmatic level faulty.

The Integrated Army Modelling and Simulation Data Network defines a technical framework for the integration of OR-systems, modules and methods in a M&S system of systems based on information management principles.

The information management process in an M&S network has its peculiarities and three domains of support can be identified:

- Method development,
- System / Module interoperability and
- Comprehensive Information Provision.

1.2 Modelling Process

All phases of the modelling process require support by a multi - functional information network.

The System Analysis Phase is based on knowledge about the “real world”. Agreed concepts, doctrines and experience based knowledge (e.g. Lessons Learned, Case Studies, Best Practise) are the baseline for a conceptual model. In the next phase the conceptual model has to be formalised by using generic modelling methods. The formal model defines parameters and their relations. Often these parameters require processed information based on field tests, results of high resolution models, method requirement (Lancaster-coefficient, Killer-Victim-tables, Meantime failure by time)

Particularly for the integration in a standardised M&S framework the new model has to be harmonised with the procedural, methodical and technical guidelines of the system framework and its components.

The requirements for a “Developers Information Network” are

- access to all standardised conceptual, formal and technical products and related documentation;
- access to unstructured information (e.g. doctrines, concepts, study reports);
- information collection and processing with respect to the model parameters and the problem definition;
- predefined model documentation guidelines incorporating the complete modelling process (incl. assumptions and restraints, information concepts, information requirements, stability, interpretation, validation).

1.3 System Interoperability

From the analytical perspective problem oriented individual solutions are more appropriate then standardised methods with a wide operative range. However it might be necessary to split complex models into interoperable micro-systems or modules. Also the integration of standardised common application services like scenario generators, terrain visualisation, data bases and evaluation tools requires interoperability guidelines.

In order to classify Interoperability, the ISC has included in their NATO Policy for C3 Interoperability (PO(2000)39), four degrees of interoperability as follows:

- Degree 1: Unstructured Data Exchange. Involves the exchange of human-interpretable unstructured data such as the free text found in operational estimates, analyses and papers.
- Degree 2: Structured Data Exchange. Involves the exchange of human-interpretable structured data intended for manual and/or automated handling, but requires manual compilation, receipt and/or message dispatch.
- Degree 3: Seamless Sharing of Data. Involves the automated sharing of data amongst systems based on a common exchange model.
- Degree 4: Seamless Sharing of Information. An extension of degree 3 to the universal interpretation of information through data processing based on co-operating applications.

The realised level of interoperability depends on the use case.

In a system of systems four levels of interoperability were identified which are a pre-condition to reach a certain interoperability degree.

- Level 1: Technical Information Exchange (You are able to talk)
- Level 2: Syntactic Information Exchange (You are able to talk grammatically correctly)
- Level 3: Semantic Information Exchange (Everybody knows what you talk about)
- Level 4: Pragmatic Information Exchange (You act logically on a common understanding)

In most cases the technical levels 1 and 2 can be realised. Due to the semantic diversity of legacy systems in Level 3 and 4 the validity of linked systems can be challenged in most cases.

1.4 Comprehensive Information Provision

Within a M&S network the organisational, data and procedural view of information provision determine the design of a future Information Management System. Based on a modern Data Warehouse architecture the Information Management System

- decouples and processes “raw information” from operative databases of external information sources into system specific Data Views or Marts,
- provides processing functions like aggregation, deaggregation, filtering and statistic evaluation as well as plausibility and consistency checks,
- reflects various information concepts of heterogeneous OR Systems and their data storage,
- provides information access within a decentralised organisational structure of the M&S community.

Information Logistic via a Data Warehouse can improve quality, integrity and consistency of the required information.

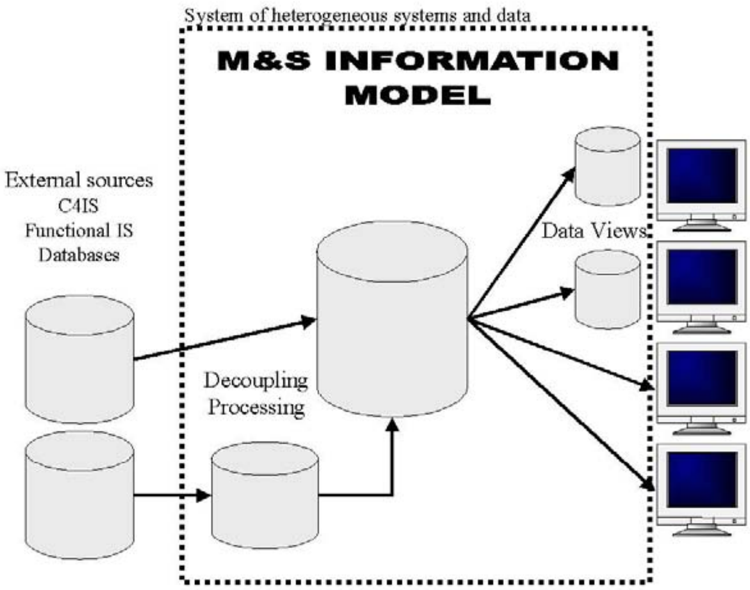

Figure 1: M&S Information Model

2 INFORMATION MANAGEMENT

As a result of the transition from the industrial to the information age knowledge represents an inherent value within an organisation. Therefore *Knowledge Management* focuses on an efficient provision and mission oriented usage of knowledge for an optimised decision support inside an organisation. Over the past years the concept of information-based warfare has been gaining in importance in military organisations. The objective of information-based warfare is to achieve a decisive military advantage by managing and using data in all of its forms. The following research findings arise from the implementation of knowledge management concepts, processes and systems in civil organisations.

- Structured and organised administration of all kinds of information and their logical relations supported by modern information technology;
- Additional information ("information about information") about the information producing organisation and process;
- Immediate access to knowledge inside and outside an organisation (searching, collecting and navigating);
- "Comprehensive Information Area" merging training, development and management;
- Simple and fast integration of new information domains via appropriate application interfaces;
- "Experience Management" by implementing a lessons learned process. and evaluating experiential information with inductive methods;
- "Information Processing" (Aggregation, Filtering, Mining, Farming, Statistic) via analytical methods to support the decision making process based on user requirements.

The scope of these basic functional and conceptual requirements can instantaneously be transferred to the M&S community. Therefore the justified claim for data engineering support in the analytical process should be broadened to an all-embracing information management concept.

The *Integrated Army Modelling and Simulation Network* Project is the first step towards a standardised information management in the M&S community.

3 INTEGRATED ARMY MODELLING AND SIMULATION DATA NETWORK

In 2000 the M&S Branch of the GE Army Office started the project “Integrated Army Modelling and Simulation Data Network”. The still ongoing activity was motivated through the omnipresent demand for interoperability and the time-consuming and cost-intensive process of creating data sets for OR Systems. The main effort is the handling of structured data in a M&S system of interoperable systems.

One major part of the project was to proof the concepts with prototypic software and experiments. The objective was to use approved architectural principles, e.g. the ISO IRDS standard, and realise them with customised Open Source products. The technical implementation is based on the use of the eXtendend Markup Language (XML) and Python. XML is developed to structure, store and send information. The language is focus on the description of data. Python is a portable, interpreted, object-oriented programming language. A huge variety of usable Open Source Projects were issued by the Python Community.

3.1 Phase 1: Feasibility Studies

Phase 1 was a set of mostly independent feasibility studies initiated through the C4I and M&S community. Phase 1 included

- a conceptual approach for a national data management process,
- a proposed architecture outline of an IT-System supporting the data management process,
- the usability of data management for M&S systems,
- the assessment of the significance of the NATO C3 Data Model as a standardised and flexible data model for the domain of Modelling and Simulation,
- the prototypical development of a configurable interface technique for data exchange of heterogeneous systems on the basis of a common data language.

3.2 Phase 2: Integrated Army Modelling and Simulation Data Network

Summarising the results of the feasibility studies the objectives of Phase 2 were

- to create and document a standardised data language on the basis of NATO’s Land Command and Control Information Exchange Data Model (C2IEDM),
- to formulate an interoperability concept of simulation systems on the basis of a common language,
- to provide simulation-specific information on the basis of the common language,
- to draft a conceptual and technical framework for an Integrated Army Modelling and Simulation Data Network,
- to prove the concepts through technical experiments by using prototypic software.

This phase was mainly carried out by civil contractors under the lead of the IABG, which were already involved in national interoperability and data management studies.

3.3 Phase 3: Proof of Concept and Evolution

The main part of Phase 3 is the proof of concept. The M&S Branch, GE Army Office is conducting an operational test to define the technical, organisational and functional requirements of an Integrated Army Modelling and Simulation Data Network.

In parallel an evolutionary development is being pushed towards the vision of a modular Modelling and Simulation Network. The Agenda of Phase 3 includes

- the integration of Common Application Services using the developed concepts,
- the extension of the standardised data language (information concepts “Command and Control”, “Finance”),
- the standardised representation of terrain and environmental data,
- the standardised representation of methods, algorithms, their parameters and relations.

4 ARMY CORPORATED MODELLING AND SIMULATION DATA MODEL

4.1 Data Modelling

M&S concepts postulate interoperability, modular architecture, reuse of components and dynamic linking. These conceptual demands have not been translated into action yet. To build federations of OR systems the required levels of interoperability standards have to be officially enforced. Level 1 (Technical Information Exchange) is covered through a variety of activities like the HLA Runtime Infrastructure, DIS, CORBA and XML. Level 2 and Level 3 interoperability (syntactical and semantic information exchange) requires a standardised information exchange language. The NATO Policy for C3 Interoperability [NC3B Sub-Committee AC/322 SC/2-WP/72 (Revised) Version 4.3] calls for “seamless sharing of data that involves the automated sharing of data amongst systems based on a common exchange model.”

Today in the M&S community the definition of information is an “art work” of every individual programmer. A common sense information concept of the M&S domain is not existent. Extensive efforts have to be undertaken to reach very limited semantic interoperability between existing legacy systems. Due to this fact the operational usefulness of linking legacy systems might be called into question. However to build future federations of network oriented systems the information domain of M&S has to be organised by an ontological design process. This process separates the meaning of information from the information content. Objects, relationships, attributes and processes are organised and documented.

Using standardised data modelling techniques and data model schemes NATO designates the ontological design process as Data Management and the ontology itself as Data Model.

The ATCCIS Project has already started to define the Land Command and Control Information Exchange Data Model (LC2IEDM) to serve as the common interface specification for the exchange of essential battlespace information. The LC2IEDM extended with a national Maritime Core Data Model was the baseline of the M&S data management activities. The results of the analysis of a wide range of simulation systems were customising or complementing the LC2IEDM. The external data representation of various constructive simulations, high resolution vulnerability models, three-dimensional constructive simulations and training simulators were harmonised and documented. The results of the initial data management activities were available in December 2002 and issued as *Army Modelling and Simulation Corporated Data Model* (*AMSCorpDM*) Vs. 1.0. Examples of appended information concepts are the “3-dimensional Location View”, “Ballistic View”, “Lethality and Vulnerability View”, “Supplemented Person View” (medical description of the human body).

The *AMSCorpDM* can be used as

- source for standardised data elements inside an OR system,
- a template for a standardised external data representation of simulation systems to support the integration in a M&S network or system of systems,
- an interface specification to get legacy systems inside the network or system of systems.

Objective is to get the standardised data elements as deep as possible inside a system.

Proceeding in accordance with the information exchange requirements and data definitions of the incorporated simulation systems the "common sense" modelling process defines information concepts on the basis of approved field-manuals, encyclopaedias, glossaries and ontologies. As a result of the semantic enrichment the system oriented mutual interface specification language migrated to a universal Modelling and Simulation ontology.

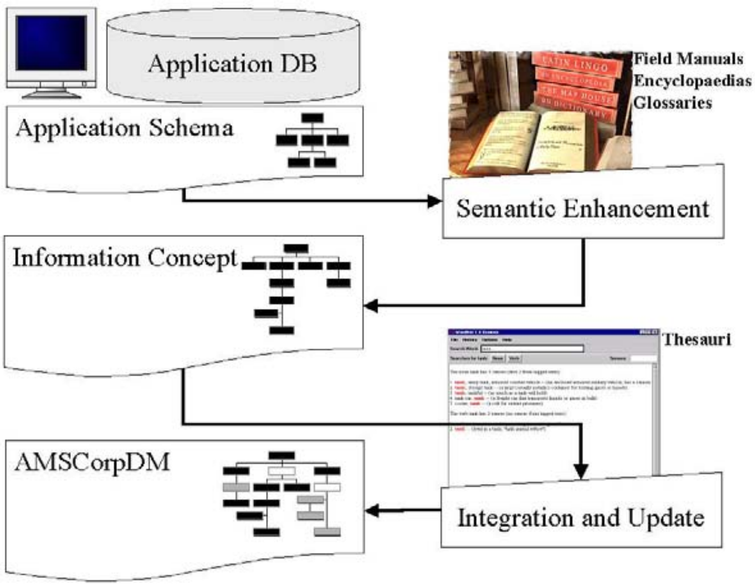

Figure 2: "Common Sense" Data Management

Adapted from the IDEF1X format an ontology schema was developed and designated as *Data Management Reference Data Model.* IDEF1X supports the semantic constructs necessary in developing a conceptual schema for a relational database. A conceptual schema is a single integrated definition of the domain data that is unbiased toward any single application and independent of its access and physical storage.

4.2 Data Management Information Resource Dictionary

The responsiveness and flexibility of the data management process is crucial for its acceptance. For this purpose a flexible and adjustable architecture of an information management system was developed

- to enable the integration in the system development process,

- to provide efficient documentation of existing standards to be used by system developers,
- to support flexible processes responding to information requirements in time to prevent delays.

The system architecture is based on the ISO Information Resource Dictionary System (IRDS) Framework.

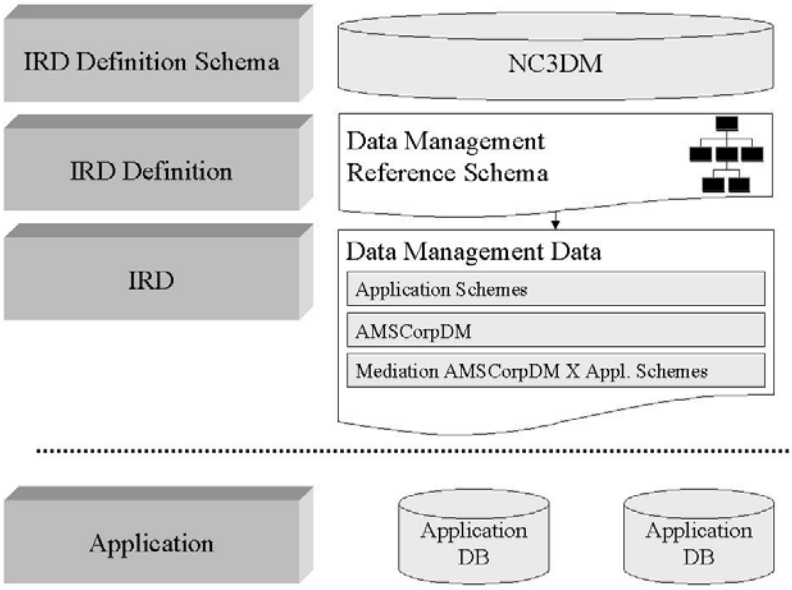

Figure 3: Data Management - IRDS

4.2.1 Layer 3 (IRD Definition Schema Level) - NATO C3 Data Model

The NC3DM as a generic data model defines the structure of the dictionary. This data model is used as a container and will be physically implemented in a database management system.

By direction of the NATO Information Systems working group the NATO C3 Data Model was created as a generic data structure to store an application data model or schema and the related application data in it. So changes to the data model are made via configuration in the NC3DM and not via software update.

4.2.2 Layer 2 (IRD Definition Level): Data Management Reference Data Model

The Information Resource Dictionary Schema of the Data Management Process (*Data Management Reference Data Model*) is defining the data management information stored in the Information Resource Dictionary.

4.2.3 Layer 1 (IRD Level): Data Management Data

At the IRD level the actual information of the data management process is stored as

- application schemes of incorporated systems,
- standardised data elements
- AMSCorpDM
- mediation rules between AMSCorpDM and application schemes.

A web based Data Management Information System (DaMIS) can be automatically created with the

DaMIRD to support system developers and data managers with all information within the Information Repository.

5 M&S DATA DOCUMENT ARCHIVE

The results of Operations Research methods eminently depends on the accuracy, integrity and plausibility of the available data. The analytical process and its embedded OR systems requires specific problem oriented data. Today at the beginning of an analytical process data collection starts as an individual sub-process. Information from different data sources is manually processed into the required system specific format. Even for common data domains like force structure, weapon system data, vulnerability and weapon effectiveness data a comprehensive source is not available.

In compliance with information management principles and data warehouse concepts a conceptual framework for a M&S data warehouse was defined:

- *Data must be available in time*. Situation oriented data collection is time-consuming. The M&S Data Warehouse has to support a routine data collection, update and amendment process. The objective is to anticipate possible information requirements to minimise the expense of individual data collection processes.
- *Data must be communicable*. The meaning of the data content has to be clearly defined for the use in analytical processes and OR methods. The available AMSCorpDM was consequently implemented as application schema for the M&S Data Warehouse.
- *Data must be relevant to the problem*. OR methods require specific data views. These data views will be kept together. After the mediation into a standardised data view based on the schema of the AMSCorpDM the data view is stored as a document in the M&S Data Warehouse. The M&S Data Warehouse is an archive of a huge number of documents. The term M&S Data Document Archive is more descriptive

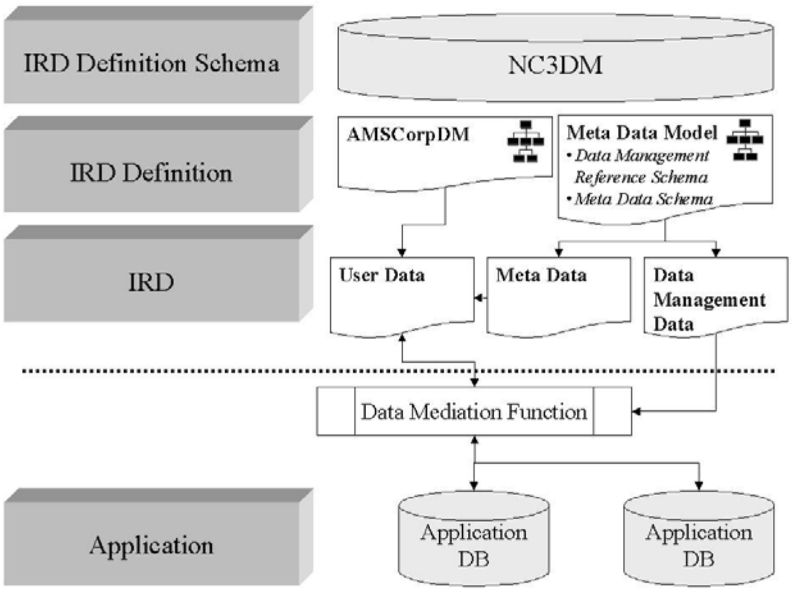

Figure 4: Dual Use - IRDS

- *Data must be retrievable*. In the sense of information management to browse, to categorise and to analyse data documents meta data have to be added to the original data document before storing in the

M&S Data Document Archive.

- *Data must be adjustable*. The use of the AMSCorpDM as IRD Schema on the IRD Definition level allows to adjust the M&S Data Document Archive schema via the specified data management process.

The concept of the M&S Data Document Archive leads to the decision to unify the functionality of the Data Management Information Resource Dictionary and the M&S Data Document Archive. Technical studies proved the possibility to store two ore more IRD Schemes in the NC3DM. Beside the *Data Management Reference Data Model* the *Army Modelling and Simulation Corporate Data Model* was embedded in the IRD Definition level defining the common user data at the IRD Level.

An XML workbench allows the enrichment of user data with meta data. The term "meta data" is not used in the sense of the ISO IRDS Framework but data which describes data. Therefore a *Meta Data Schema* was defined. It includes semantic definitions for the data originator, status of verification, validation and accreditation, context and topic, reliability and accuracy. Navigation and searching in the XML document archive will be ensured via predefined Frequently Asked Questions provided by the Query Workbench. All data manipulation, data aggregation and statistical evaluation functions can be realised as a process oriented XML editor.

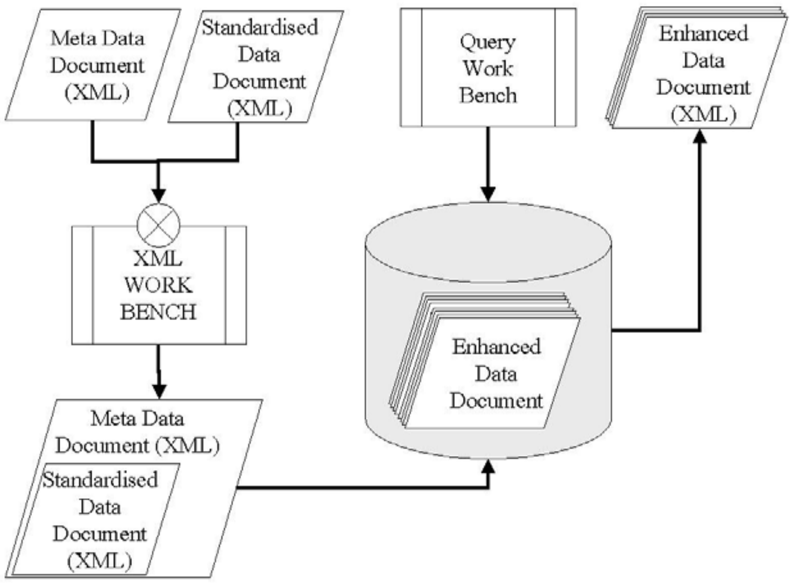

Figure 5: M&S Document Archive

6 SYSTEM INTEGRATION PROCESS

The concept of an XML-based framework for a M&S system of systems requires a minimum of pre-conditions. Every system which uses XML for data export and import can be integrated as federate. The optimum would be if federates already incorporated the standardised semantic and syntax of the AMSCorpDM.

The present legacy systems are not designed to communicate in a standardised environment or do not possess documented and standardised Application Programming Interfaces. Therefore the individual data representation of an application has to be transformed into an XML structured data document via a System - XML Proxy. For the mediation process the individual logic data model of this system specific XML data document has to be documented in a template and imported as application schema into the Data

Management Information Resource Dictionary. The structure of the documentation template is based on the IDEF1X notation.

To get a standardised data document the individual application schema of the system data document is mapped on the AMSCorpDM. The mapping rules are documented in a mediation template and in the DaMIRD. This Mediation Template will initialise the Data Mediation Function (DMF). The DMF is a configurable interface software which supports the data migration from a system data document into standardised data document. The software can be integrated into systems to provide a standardised data import and export functionality based on XML and the AMSCorpDM.

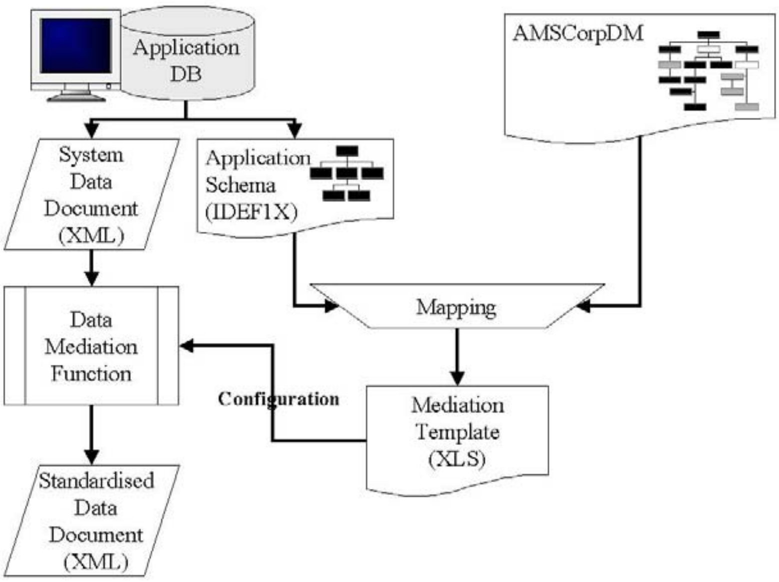

Figure 6: System Integration

The data exchange from system A to system B can technically be realised as crosswalk from the individual data document (A), mediated to the standardised data document (A) in the AMSCorpDM language. Overlapping information concepts of standardised system data document (A) with standardised system data document (B) can be transformed directly, gaps and semantic differences have to be bridged by Application Gateways.

Document Name	Originator	Format	Schema
Application Database	Application	Individual (ASCII, DBMS, XML,...)	Individual
System Data Document	Application	XML	Application Schema - IDEF1X
Standardised Data Document (System View)	Data Mediation Function	XML	AMSCorpDM (System View)
Meta Data Document	Manual / XML Work Bench	XML	Meta Data Schema
Enhanced (standardised) Data Document	XML Work Bench	XML	AMSCorpDM & Meta Data Schema
Application Schema	Manual	XLS-Template (IDEF1X)	Meta Data Schema (Data Management Reference Schema)
Mediation Rules	Manual	XLS-Template (Mediation)	Meta Data Schema (Data Management Reference Schema)
AMSCorpDM	Manual	XLS-Template (Data Management)	NC3DM

Table 1: Document Overview

The same methodology can be used to realise the information exchange between OR systems, C4I systems and other IT systems.

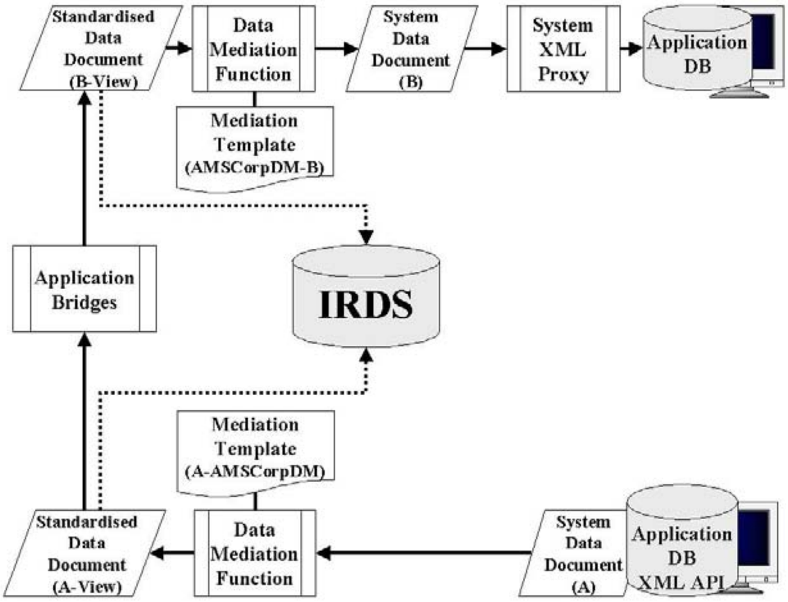

Figure 7: Data Exchange

6.1 Multi-Role Common Platform

The functionality of the unified M&S Data Document Archive / Data Management IRDS is tailored to different roles depending on the supported processes and the required information of an organisation. The Multi-Role Common Platform supports data management, data provision, data processing and data exchange. The process tailored satellites can be linked into an Army M&S Integrated Data network which forms an eminent component of a future M&S system of systems or M&S network.

7 CONCLUSION

Starting from national and international concepts and standards an operational and technical architecture of an Information Management System was developed. Experiments proved the feasibility and practicality for various simulation systems. However it is one of the preliminary steps towards a M&S system of systems. One major future task is to enforce the implementation of the approved standardisation activities.

In December 2004 the GE Army Office will issue a final project report and will come forward with a proposal for the further way ahead.

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INTEROPERABILITY BETWEEN THE RNLA C2 WORKSTATION AND THE 'KIBOWI' CONSTRUCTIVE SIMULATION TOOL FOR OPERATIONAL SUPPORT AND TRAINING

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SUMMARY

The Royal Netherlands Army (RNLA) is currently developing the C2 WorkStation (C2WS), which is a configurable, distributed information system that provides generic functionality to support the Command and Control process. One of the main tasks of the C2WS is to support the users in building and maintaining a Common Operational Picture (COP) that provides adequate situational awareness. TNO-FEL has performed experimental studies on the C2WS to investigate the issues related to interoperability between C2 systems and simulators. The aim is twofold : support the staff training process by using the C2WS as an interface between trainees and simulation tool ('train as you fight') and investigate the options for operational C2 decision support tools based on simulators.

The RLNA performs staff training through Computer Assisted eXercises (CAX) with the 'KIBOWI' constructive simulator. Currently manned Lower-Control cells provide the interface between the simulation and the trainees. The vision for the future is to develop more automated interfaces between the simulator and the C2 systems. The simulation will provide stimuli to the C2WS (e.g. unit detection or displacement) and thus interact with the trainees through the operational C2 systems. Instructors can now also better assess the user's performance with these C2 systems. Interoperability with Decision Support Systems (DSS) concentrates on Course of Action (COA) analysis and mission planning. The mission plan is defined in the C2WS and automatically transferred to the DSS. The DSS analyses this input through simulation and predicted results (e.g. rendezvous times) are routed back into the C2WS as a new planning overlay available for evaluation by the C2 operator.

The architectural approach to our interoperability need is to provide a software gateway between the C2WS communication network (based on XML messaging) and the High Level Architecture (HLA) standard. The link to HLA provides the possibility to connect many modern simulation components to the C2WS architecture. The HLA development process that was followed provides a generic approach to simulation interoperability for the C2WS. This process concentrates on defining a datamodel that matches the requirements and features of both the C2 system and the available simulation assets.

This paper presents an overview of the possible use of interoperability between C2 systems and simulation systems, an overview of the architecture, the development of the demonstrator and our results to date.

Paper presented at the MSG-022/SY-003 Conference on "C3I and M&S Interoperability", held in Antalya, Turkey, 9-10 October 2003, and published in RTO-MP-MSG-022.

1. INTRODUCTION

This paper addresses the approach used by TNO-FEL to develop and demonstrate concepts for interoperability between C2 systems and Simulations. Simulation interoperability for C2 systems enables applications in training of military users, operational support, procurement and assessment and evaluation of C2 systems. The presented project is aimed specifically at the Command & Control Workstation (C2WS), a new C2 information system for the Royal Netherlands Army (RNLA), which is under development. The requirements for the design of the C2-Simulation interoperability architecture are: flexibility, scalability, robustness and compliance to international standards.

As a first demonstrator of interoperability between C2 systems and simulations, the coupling of C2WS and the KIBOWI wargame, an HLA (High Level Architecture) based Simulation system, was chosen. The demonstrator concentrates on providing improved Situational Awareness (SA) for trainees by means of the C2WS.

The next section of the paper addresses the need for interoperability and the general concept of coupling C2 systems to Simulations. Sections 3, 4 and 5 explain the background for the C2WS, KIBOWI and HLA. The following sections discuss the system architecture, implementation issues and some results and conclusions of this project.

2. LINKING C2 SYSTEMS TO SIMULATION MODELS

Linking C2 systems to Simulation systems has many potential applications. Simulation systems can stimulate the C2 system by providing data that simulates the 'real-world'. This information will appear to have been received from peer C2 systems. In this way a simulated COP (Common Operational Picture) is created that is based on a simulation scenario. Applications of this technique are: assessment of C2 systems (performance, user interface etc.), assessment of C2 operator capabilities or training of C2 operators. The simulation can provide the C2 operator with operational decision support by executing 'what-if' scenarios. These scenario's can support the operator in his decision making process (e.g. mission planning or assessment of alternative COA's). New or experimental parts for an existing C2 system can be evaluated before purchase or even before full development of the component by replacing an existing component of the C2 system with an embedded or external simulation. Simulated systems can be 'initialised' from the existing COP in the C2 system and a simulation run can be started based on this information. The advantage of using simulations as a tool for stimulation of C2 systems, as opposed to 'role players', is that the simulation has a consistent, controlled and reproducible behaviour, which allows objective assessment of system and/or operator performance. TNO-FEL has recognised an opportunity to support the C2WS assessment activities and the current C2 staff training process by ongoing experimental studies on coupling of our simulation tools with C2 systems. The aim of the research is to develop a flexible and future-proof approach to the C2-Simulation interoperability problem. First we need to clarify what we really mean by 'interoperability'. Interoperability is the degree to which entities are able to co-operate in achieving a common goal. There are many interpretations of the concept of interoperability between computer systems. It varies from having a network connection and being able to transfer files (e.g. email) to using exactly the same applications at all systems and completely sharing the information they process. A commonly used form of interoperability is *'information interoperability'*, because it offers optimal connectivity between systems, while preserving maximum independence. Information interoperability is defined as the ability of systems to automatically exchange and interpret information that is common to those systems [1].

In this paper we focus on information interoperability that is achieved by the *automated exchange and* *interpretation of structured information* between systems. With minimum user intervention, C2 systems and Simulation systems must be able to *automatically* interchange certain information and utilise that for further processing. This means that the information must be *structured*, because this enables functionality such as distribution by subscription on certain topics, presentation of information and filtering by specific selection criteria. The emphasis here lies on the exchange of *information* (rather than 'free format' databits), preserving its meaning, integrity and context. Structured information is described formally by a *'Datamodel'*. The datamodel thus represents the foundation for information interoperability. In the most common case where many systems have to exchange information, standardisation of a common 'interface' is a key factor to achieve information interoperability. Otherwise, dedicated interfaces are needed between every pair of interconnected systems, leading to an exponential growth of the number of interfaces required [Figure 1],[8]. Preferably the exchange should not depend on proprietary products, such as database management systems and communication systems.

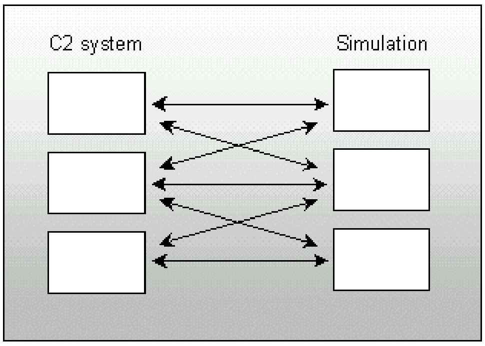

Figure 1 C2 and Simulation Interoperability (dedicated interface)

The key notion for information interoperability is *standardisation*. By having common agreements on which information is exchanged, in what format, and under what conditions, it becomes easier to allow systems of different types to interoperate [Figure 2].

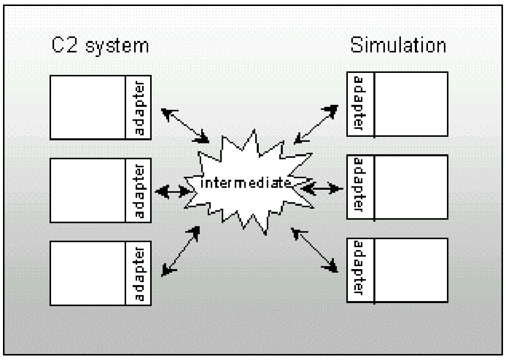

Figure 2 C2 and Simulation Interoperability (standard interface)

3. COMMAND & CONTROL WORKSTATION (C2WS)

The C2WS [Figure 3] is a configurable *application platform* and information system that provides generic functionality to support the Command and Control process. The C2WS supports the users in building and maintaining a COP that provides adequate Situational Awareness. The C2WS is being developed at the RNLA C2 Support Centre, with co-operation of TNO-FEL. The system architecture of the C2WS comprises of three layers: presentation services, business services, and data services.

The **presentation services layer** is responsible for gathering information from the user and presenting information to the user using the services of the business services layer.

The **business services layer** is responsible for end-to-end *business transactions* such as maintaining *roles*, *contexts* and *business objects* and the logic that applies within these concepts.

The **data services layer** is responsible for storage, retrieval, maintenance and integrity of data. The data services layer is also in charge of publishing as well as subscribing and listening to data on the C2 network.

The information exchange in the C2WS environment is implemented through a middleware layer named 'C3I Framework'. The middleware follows the RNLA C3I Architecture (C3IA) Information Model (C3IA-IM) for C2 applications within the RNLA [2]. The C3I Framework uses commercial of the shelf publish/subscribe services (Tibco Rendezvous) and a tailored information exchange language based on XML messaging. The C2WS has conversion modules for RNLA legacy systems such as the Integrated Staff Information System 'ISIS' and for the future Battlefield Management System 'BMS'.

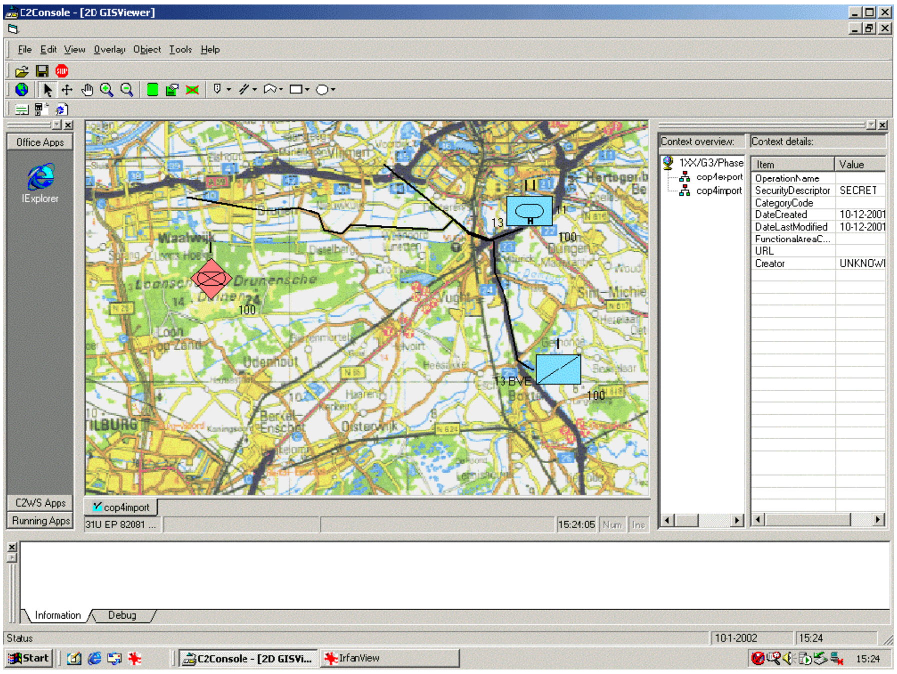

Figure 3 C2WS GUI (RNLA prototype)

At the time of writing, the C2WS supports GIS functionality for placing units and lines/areas on the map. The network functionality is partly implemented, for example updates of the COP for a certain 'context' can be exchanged between different C2WSs. However a means for a new C2WS to hook into the network and receive the full current COP has not yet been implemented.

4. KIBOWI

KIBOWI is a detailed constructive combat simulation model that takes into account manoeuvre, fire support, combat engineering, air defence, air support, combat service support operations and amphibious operations. The model is capable of simulating ground operations at battalion, brigade and division levels.

KIBOWI can represent entities on a platform (e.g. vehicle) and aggregate (e.g. platoon, company) level. KIBOWI is normally used by the RNLA as an exercise driver for Command Post Exercises (CPX). Some other users are Belgian brigades and the Bulgarian army. Primary training audiences are typically staffs at battalion, brigade, and division level.

In the C2WS-KIBOWI federation KIBOWI drives the demonstration scenario by providing an operational context for the mission. The operational context simulated by KIBOWI consists of formations of own and hostile ground forces. These units provide a dynamic and representative environment for the C2WS operations. During a scenario run, each KIBOWI unit executes a predefined list of orders. This eliminates the need for user interaction during execution and ensures repeatability of the scenario.

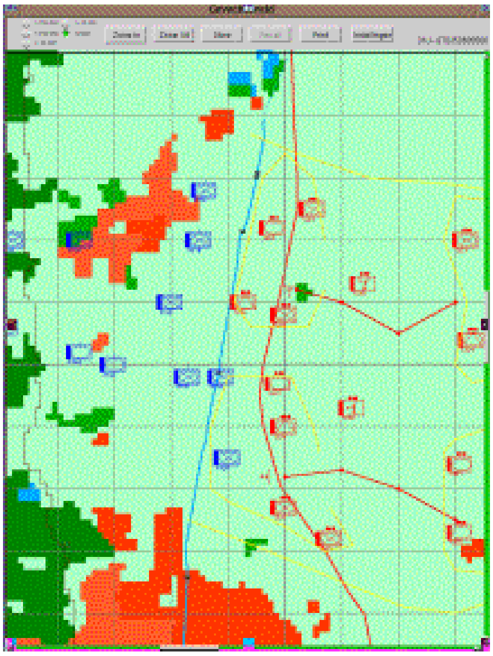

Figure 4 KIBOWI GUI

KIBOWI simulates both aggregated and platform level entities in the scenario. Since KIBOWI is not capable of aggregating and de-aggregating units dynamically, care had to be taken during scenario design that no interactions would occur between KIBOWI aggregate units.

An HLA compliant version of KIBOWI was developed in the context of the NATO DiMuNDS 2000 project. Because no RTI implementation was available for the platform that the KIBOWI software runs on (i.e. OpenVMS on Digital AlphaStation), KIBOWI uses a gateway component to link to the HLA.

The C2WS-KIBOWI federation adopted the DiMuNDS 2000 datamodel with only a limited number of modifications. Therefore, the KIBOWI HLA gateway could be adapted easily to the new federation (mainly the mapping functions were affected). No changes were required in the code of KIBOWI itself.

5. HIGH LEVEL ARCHITECTURE (HLA)

The High Level Architecture (HLA) is an architecture for reuse and interoperation of simulations [3], [4], [5], [Figure 5]. The HLA is based on the premise that no single simulation can satisfy the requirements of all uses and users. An individual simulation or set of simulations developed for one purpose can be applied to another application under the HLA concept of the Federation: a composable set of interacting simulations.

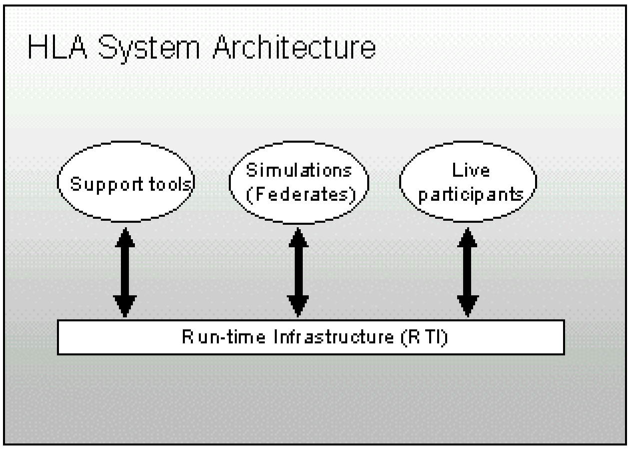

Figure 5 HLA Federation

The intent of HLA is to provide a structure that will support reuse of capabilities available in different simulations, ultimately reducing the cost and time required to create a synthetic environment for a new purpose and providing developers the option of different implementations within the framework of the HLA. The baseline definition of the HLA includes the HLA Rules, the HLA Interface Specification (IFSpec), and the HLA Object Model Template (OMT). The HLA interface specification defines the services that HLA provides to the application. These services include Object Management (publish/subscribe) and Time Management (i.e. synchronisation between distributed applications). The Federation Object Model (FOM) is the datamodel of the HLA Federation. The OMT is the standard datamodel format that is used in HLA documentation. The HLA specification was adopted by the US Defense Modelling and Simulation Office (DMSO), by NATO and it has now been accepted as IEEE Standard 1516 for simulation interoperability. Development of a generic coupling between C2 systems and HLA thus provides the possibility to connect modern simulation components to the C2 environment.

One of the main components of HLA is the Run-Time Infrastructure (RTI). The RTI implements the HLA IFSpec and allows the user to invoke the RTI services to support run-time interactions among Federates and to respond to requests from the RTI. This interface is implementation independent and is independent of the specific object models and data exchange requirements of any Federation. At TNO-FEL we developed an HLA based middleware layer, called the Runtime Communication Infrastructure (RCI) [6] which supports HLA. The RCI shields the developer from many intricate details concerning the usage of the HLA-RTI when developing either a Component or a Federate. The RCI includes a C++ code-generator to translate the required HLA-OMT descriptions into easily accessible object-oriented classes.

6. BRIDGING THE GAP

Previous attempts to couple C2 systems with simulations were often ad-hoc and resulted in tailor-made connections for every specific combination of C2 systems and simulation models (See also references in [8]). A new connection had to be developed for each new system that needs to be included. This approach means a lot of work for both the C2 system and the simulation models, [see Figure 1]. A more flexible approach is the use of an intermediate layer as show in [Figure 2].

Once a system or simulation has a (tailor made) adapter for the intermediate layer, the system can be connected to other systems or simulations without any additional work on the other players.

The approach that was followed to achieve C2WS-Simulation interoperability resembles the 'intermediate layer' solution, however with an important difference: both the C2WS systems and the Simulation systems already support interoperability within their own domain.

The C2WS system uses the 'C3I Framework' middleware, which is based on Tibco/Rendezvous. The simulation systems use the HLA interoperability standard. We have developed a 'Tibco-HLA gateway' to connect TIB/RV on one side to HLA on the other side (see Figure 6).

In addition to interoperability at the technical level (protocols, networks etc), we also need to develop the information interoperability for the gateway which aligns the Datamodels and provides a two-way mapping for all relevant attributes. HLA federates define their data exchange via a Federation Object Model (FOM). The FOM has to be agreed upon between the systems that need to be connected. For the C2-Simulation system a C2WS-KIBOWI Federation has been designed together with an initial FOM based upon the FOM used previously in the NATO DiMuNDS 2000 demonstration [7].

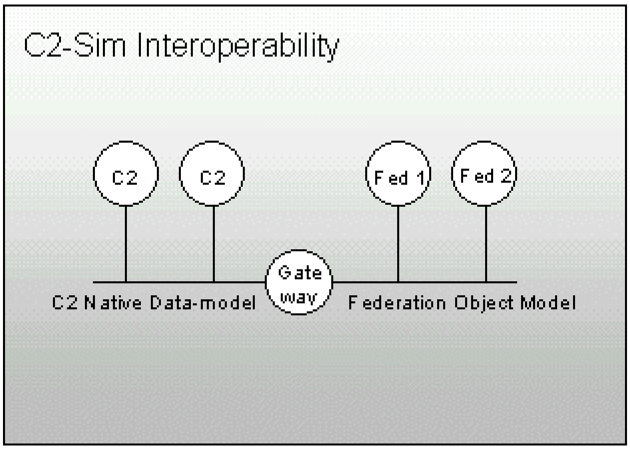

Figure 6 C2-Simulation Datamodel Interoperability

This FOM describes four generic objects, which are :

- Weather,
- Stationary,
- StationaryMultiLocation and
- Mobile

The information that is exchanged via the FOM consists amongst other things of the position of the object and depending on the object information, for example status and speed. Given the different development history of the C2WS and the DiMuNDS FOM it is often impossible to directly map the information exchanged between C2 systems onto the FOM.

In most cases it is necessary to combine information from the C2 system in order to get it mapped onto the FOM and vice versa. For example, the following fields were identified for a unit message that need adaptation before they can be mapped on either the FOM or on the C2 information.

Table 1 Data mapping fields (not exhaustive)

FOM	C2WS
ObjName	Name
PartyNumber	Nationality
Velocity	SpeedQty
Position	Position
Front	BearingAngle

A name in the FOM needed to be restricted to 10 characters, the FOM only knows of four different parties while the C2WS allows many more different nationalities, and the location of a unit in the UTM system of the C2WS needed to be translated into the relative map co-ordinates used by the FOM. Specific conversions and layout issues had to be resolved and implemented to realise any coupling between the two domains.

The C2WS-HLA Gateway was developed for the purpose of incorporating a C2WS in the Federation. This Gateway (see Figure 7) was implemented using two processes, one attached to the RCI (HLA middleware) and the other attached to C3I Framework. Both sides use a publish/subscribe method to distribute data on their respective networks. The C3I Framework listens to messages on the C2 network and places an image of the object/interaction data concerning the C2WS entities (to which a subscription was issued by the Gateway) in shared memory. The RCI process subsequently reads this data from shared memory and maps it onto the HLA-FOM via the RCI middleware. The same holds for communicating data from the HLA Federation to the C2WS world where the C3I Framework publishes and updates the object/interaction data received from the Federates in the simulation.

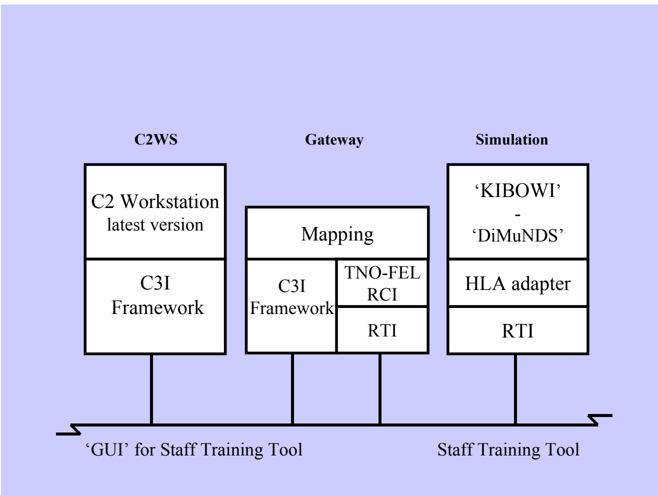

Figure 7 C2WS Federation with C2WS-HLA Gateway

The Gateway code is currently 'handcrafted'. Development of a Codegenerator tool that translates C2WS object structures into 'OMT' like datastructures would simplify matters. Such a tool would effectively turn the C2WS-HLA Gateway into an OMT-to-OMT mapping process.

7. RESULTS

The prototype demonstrator for the C2WS-KIBOWI federation is capable of generating a COP image on the C2WS based on data received from KIBOWI ('oneway' traffic). The gateway handles a limited set of units and other C2 items, which shall be extended in further versions of the demonstrator.

Due to the early stage of the development of the C2WS, some cumbersome precautions have to be taken when demonstrating the simulation functionality. The COP updates on the C2WS are incremental, so only changes are broadcast to other C2 stations. A full COP transfer for when a new C2WS is added to the network, or in our case, for simulation purposes, has not yet been implemented in the current version.

Implementing a coupling of this RNLA C2 system with a simulation component in such an early stage of its development has resulted in encouraging insights in the possible additional functionality required of the C2WS and indeed other C2 systems.

8. CONCLUSIONS AND FURTHER WORK

The demonstration system achieved its overall objectives and so far received positive reactions from its audience. Some lessons learned to date from the project are:

- Use a single (authoritative) source for common data like terrain maps and data, co-ordinate conversion algorithms, equipment and weapon parameters, etc.;
- Test and Evaluation of C2WS prototypes in a simulated environment is very cost effective;
- Operators need to become aware that C2WS response is not 'real-time';
- Operators need to become aware that C2WS information is not always the 'truth'.
- Pursue for a standardised C2-Simulation Datamodel, represented in FOM format.

In addition to full compliance with HLA, the innovative architectural concept that was developed supports the key capabilities required for future C2-Simulation interoperability applications :

- An abstraction layer (e.g. TNO-RCI middleware) and a code generator hiding complexities of the underlying simulation interoperability standards and enabling simulation protocol migration with minimal changes to the functional implementation.
- A structured development process (the FEDEP [5]), supported by appropriate tools, enabling migration of legacy simulations and COTS products to the new standard architecture;
- The Gateway approach as the optimal solution to allow interoperability between the different worlds that C2 and Simulation are today. It is unlikely that one single standard for all information exchange between systems is achieved in the near future, even if we restrict the 'universe' to NATO C4I systems.

The (completion of the) design and the development of the C2WS falls outside the scope of our project. However, we do believe that future C2 systems will include the design requirement for interoperability with simulations and the results of our project will therefore influence the development direction of the C2WS. The C2WS is on its way to become a useful and exciting new C2 system, reaching out to the useful and exiting new simulation standard HLA.

The RNLA is planning to support staff training with the Midlife Update (MLU) of KIBOWI. This MLU is now being developed by TNO-FEL. The MLU will have the following additional features:

- The MLU is coded in JAVA, this provides platform independence (e.g. Windows, Linux, Unix) and eases maintenance.
- The MLU is internet based (TCP/IP). This makes remote training with an internet connection possible.
- The MLU provides multiple modes of use; e.g. the warfighter setting 'train as you fight' and the classroom setting.

The demonstrator will be developed into a fully operational coupling between the C2WS and the MLU of KIBOWI. The first application will be support for staff training. The Gateway will be extended with more sophisticated filters and features that allow instructor control over which entities are transferred (e.g. blue only) and provide additional options to delay the transfer of 'red' unit position updates as if these were the result of observations.

Future research work will focus on the use of KIBOWI as an operational support tool for the C2 process. KIBOWI will evaluate and analyse COA's prepared on the C2WS. This type of simulation based decision support tool provides the commander with a range of new possibilities. This next version of the demonstrator will require a 'two-way' communication between the C2WS and KIBOWI.

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NetSim – A Network Based Environment for Modelling and Simulation

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ABSTRACT

Modelling and Simulation (M&S) is a powerful tool that is used to support training and analysis of military operations, development of military concepts and gradually, it is becoming an integral part of modern C3I systems. As the web has evolved, new ways of carrying out modelling and simulation and realizing C3I systems have emerged. These achievements address some of the research issues considered vital for future development of the M&S/C3I domain. Firstly, web related technologies provide means of overcoming the interoperability barriers, for example through standardized data exchange formats (such as XML), platform independent software (for example Java) and shared knowledge of a domain (semantics). Secondly, networked environments offer ways of setting up virtual organisations, sharing common goals and interests, to efficiently collaborate in problem solving. Finally, computer networks promote efficient sharing of resources, which for example could increase the reuse of existing models or utilize idle processing capacity of computers.

At the Swedish Defence Research Agency (FOI) there is ongoing research, targeting the role of network/web based technologies in M&S, to support defence communities in their work. Our vision comprises an environment supporting the entire M&S-process, including conceptualization, scenario definition, design, development and execution. All these tasks should be maintained by a framework for collaboration, which lets users; developers, analysts, administrators etc, jointly work on a project. During the first phase of this research focus has been on efficient resource sharing and means of collaboration. Through experimental research and implementation of a prototype (NetSim), methods and techniques have been identified to form a framework for collaborative work, resource management and distributed execution.

Following current trends within development of networked applications, decentralized (Peer-to-Peer) solutions were of primary focus when implementing the prototype. Based on the open source Peer-to-Peer platform JXTA, two distinct components of our envisioned system were implemented, namely; a decentralized resource management system deploying a network of workstation for execution of HLA federations and a collaborative environment for joint modelling of federations. Our results show that the utilization of Peer-to-Peer concepts for resource sharing and collaboration are favourable in terms of scalability, robustness and fault tolerance. The technology allows formation of virtual organisations without the need of intermediate resources like centralized and powerful servers. However, some aspects of our implementation temporarily rely on central control, thereby diminishing the benefits of the Peer-to-Peer paradigm. Future research will therefore address distributed algorithms for synchronisation of

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collaborative work and a more flexible and extendable approach to resource management. Furthermore, as many studies have pointed out before, one of the great challenges of any type of Peer-to-Peer system is discovery and matching of resources. This is an area that deserves great attention when planning for the next generation C3I/M&S tools.

1 INTRODUCTION

C3I systems of the future Network-Centric Defence are dependant of the network and require interoperability between different components of the system. During the past decades the modelling and simulation (M&S) community, particularly the area of distributed simulation, has explored the possibility of coupling live and simulated systems in joint exercises and hence addressed the interoperability issues from many perspectives. Therefore, many of the challenges that future C3I systems are facing have already been dealt with by the M&S community.

M&S as an integrated part of C3I systems could provide means for decision support, simulation based acquisition, planning, training, etc. Furthermore, M&S could be employed as a tool for development of C3I systems, e.g. for studies, test and verification. The mutual benefit of a close collaboration between C3I and M&S systems has been identified and discussed during recent years [1] and the High Level Architecture (HLA) has been suggested as a mean to interface and increase interoperability between the two systems.

The High Level Architecture (HLA) is an IEEE[1] standardized architecture (HLA 1516), that provides means of connecting independently developed components (federates) to form simulations (federations). A simulation is formed by connecting individually developed components to a Run-Time Infrastructure (RTI), which implements the HLA standard. The RTI resembles a distributed operating system for simulations by providing services that enable interaction between participating components [2].

Integrated computer based decision support tools have also been identified as an important part of future C3I systems [3]. The fundamental idea is to make decisions faster and at the same time improve the quality of the decisions made. Tools that are accomplishing this are generally based on simulation systems, which often require interoperability and collaboration between different actors, such as decision-makers, field commanders, and technical staff etc. To realize these ideas efforts have been made within the area of computer based collaboration, enabling sharing of various resources, work areas, tools and environments. These techniques will not act as a substitute for real human-human work, but can be used for bridging distances and increasing and facilitating cooperation.

An evolving technology that could provide a fundament for modern C3I systems is Peer-to-Peer (P2P) [4, 5]. The technology offers advantages such as live peer interaction and collaboration, ad-hoc networking and robust and fault-tolerant systems through redundant application and communication paths. P2P-technologies aim at utilization of resources at the edges of Internet as opposed to the traditional client-server model. P2P can be seen as an alternative network architecture that doesn't exclude, but does not naturally build upon centralized solutions [6]. Essentially, P2P is about community and mutual sharing of resources, by organizing nodes into groups sharing common interests and goals.

The aim of this paper is to give an overview of work related to web/network based modelling and simulation carried out at the Department of Systems Modelling, Swedish Defence Research Agency. Moreover it provides an insight in ongoing research in this area and its relation with integrated M&S/C3I systems.

[1] The Institute of Electrical and Electronics Engineers

2 BACKGROUND

2.1 Interoperability

Connecting systems of various types developed for different purposes, during different technological eras and for different platforms, inflicts major difficulties, especially in terms of interoperability. It is required that systems are capable of communicating between them, but also that the communication is semantically and syntactically agreed upon. If these basic requirements are not met, systems may interoperate for the wrong reasons. The problem of interoperability is important to address in the management of highly distributed systems like distributed simulations and C3I systems. The issue of interoperability has been of major concern within the modelling and simulation community for some time now. Already during the 80's, efforts were made to standardize distributed simulations to facilitate interoperability among simulators, simulation models etc. The efforts made and experience gained in this forum, are definitely worth considering when planning for and developing integrated future C3I – M&S systems. Moreover, the rapid development of web/network related technologies brings new possibilities for overcoming the interoperability barriers and problems related to availability and management of resources. For example, through new ways of exchanging data (XML), distributing resources (P2P and Grid computing), and assuring semantic and syntactic correctness (Semantic Web initiative[1]).

2.2 The NetSim project

In 2001 a project was initiated at the Department of Systems Modelling, FOI, with the goals to manage and facilitate some of the issues concerning simulation interoperability, availability and reusability. The project was called WebSim, and focused on the area of web-based M&S. It produced interesting result regarding adapting legacy simulations to the web, and also concerning implementing HLA federations for web-based composition and execution. Some of the work was reported in [7].

As a follow-up to WebSim the NetSim project was formed. NetSim is a shortening of the full name *A Network Based Environment for Modelling and Simulation*. The new project does not reject the ideas of web-based M&S, but instead extends the concept. The main directions are to investigate decentralized solutions for M&S in general, both web-based solutions and other possibilities. For this cause a prototype environment is being developed. It is intended to provide functionality and tools for the complete M&S life cycle, all the way from design and simulation modelling, to execution and documentation. The NetSim environment shall also provide access to distributed resources such as simulation models, various data, or even CPU usage, as aid for M&S activities.

NetSim is intended for use within several different defence systems. It will support computer-based collaborative work, such as shared work areas and means of communication. This means that NetSim will not only work as a common platform for M&S, but also as a place of meeting for (M&S) people. In the computer environment, software developers, Subject Matter Experts (SMEs), soldiers and VV&A people may meet, and use and share each others' resources and expertise. In modern and future defence systems M&S is used as technical aid for decision making, Simulation Based Acquisition (SBA), logistics planning and military training etc. Hence, NetSim could constitute an excellent tool for those systems and activities, and for activities where M&S is not currently used, but would be beneficial if made possible. An example of this is the support for mobile clients such as PocketPCs. This allows people on the move to interact with the environment. Hence a soldier may receive direct access to data and information about supplies and routes, and may collaboratively plan or decide what forthcoming actions to take. This also means that dynamic and actual data can be transmitted back to the base, and more optimized and well-planned decisions can be made easily. The NetSim environment will allow people (nodes) within a network to collaborate through their computers, which makes it easier to create a common picture of the

[1] The semantic web is a web of machine-readable information [8].

situation/problem to handle, and supplied direct contact between all actors concerned. It hereby allows immediate access to the competence and expertise needed.

2.3 The NetSim environment prototype

At present a NetSim prototype is implemented. The prototype is not yet complete, but it demonstrates useful functionality and what the environment can be used for if employed in defence systems. It is implemented as a lightweight Java application, in which a user retrieves access to M&S tools and distributed resources within a local network. In order to let various kinds of users access NetSim, who may be located in different computer environments, a set of requirements were identified and followed during the design phase. These declare that the implementation should be:

- Flexible – Supporting different users with varying computer capacity and properties to utilize the system
- Scalable – In critic situations the number of users must not affect the system capacity
- Platform independent – As much as possible the implementation should be kept platform independent
- Technology independent – The result of our work is primarily the concepts being designed, not the implementation. Hence the solution is kept as technology independent as possible
- Extensible – The infrastructure must allow for further integration of new systems and functionality

All simulation modelling and execution is today performed according to the HLA for purposes of project directives. The system is based on a distributed infrastructure implemented with P2P technology, see 2.5 – 2.6, which provides means for resource sharing and distributed computing among others. It allows users to search for, locate and access distributed resources and users in the network. Resources may in this case be anything from simulation models to CPU usage. Within NetSim only a few simple tools are currently provided, such as a text chat, an application for managing resources, and a graphical modelling tool, in which a user may compose HLA federations out of HLA federates residing within the network. A snapshot of the graphical M&S tool is shown in figure 2.1. Users can also run and view the composed HLA federations from the environment. The execution is performed transparently to the user, within the P2P network, through efficient utilization of idle processing capacity in desktop computers.

2.4 Areas of research

When designing NetSim, we identified some areas of significance to networked environments and network based M&S in particular. We decided to focus on a few, which are:

- Component-based M&S – Allowing reusable, easily distributed simulations
- Standards and techniques for M&S – Distributed, reusable simulations set high requirements on interoperability
- Thin clients – Involving not only PCs and web-based clients in the M&S system, but also PocketPCs and others
- Collaborative environments – Environments that provide a common picture of the problem to solve. Involving problems of maintaining consistency and control within the collaboration group
- Resource utilization – Efficient ways of utilizing distributed resources, through efficient resource description and allocation

Of the issues listed above, the last two have been the key issues in previous and current work. The collaborative work is described in chapter 3, and the resource utilization in chapter 4. More technical descriptions of these have been presented in two papers [9, 10].

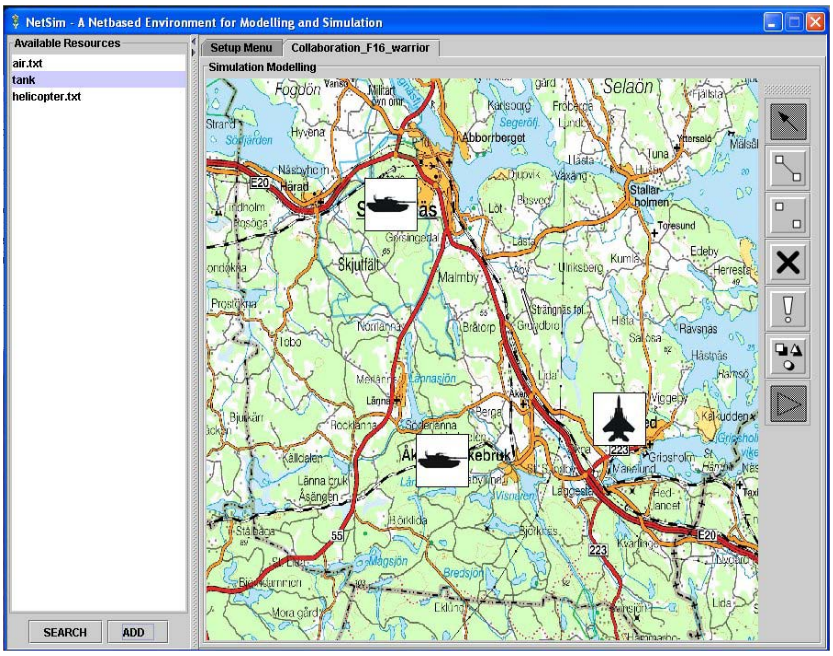

Figure 2.1: Snapshot of graphical modelling tool in NetSim. Users may (collaboratively or not) compose HLA federations out of HLA components (federates) residing in the network.

2.5 Peer-to-Peer Based Resource Sharing

Peer-to-Peer (P2P) as a concept for computer communication is nothing new. In the early sixties, the pioneers of ARPANET formulated their vision of a future computer network comprising host-to-host capabilities. In their vision all connected nodes were equal in terms of functionality and could access resources from any other computer on the network [11]. These early ideas have not greatly influenced how the Internet is used today. The dominating architecture is the client-server model, where resources of various kinds tend to accumulate at dedicated centres. Large parts of the Internet remain unused, as network traffic around certain spots shows increasing activity. However, in the past years ideas and technologies have been put forth that promote the idea of distributing resources through use of P2P technologies. The distribution of resources is advantageous from many aspects; it reduces the occurrence of bottlenecks, minimizes possible system downtime and increases system availability and robustness etc.

P2P has definitely made a great impact on how ordinary desktop computers may communicate and exchange various resources. This is especially true for the so called file sharing applications, although they are heavily questioned in terms of legal property rights. However, some more academic projects have successfully confirmed the strength of P2P for distributed computing. The Intel Philanthropic P2P program has demonstrated utilization of idle processing capacity in desktop computers to solve problems within the medical domain [12], whereas the SETI@Home project represents a successful P2P model for distributed computing, used for processing of radio astronomic data [13].

2.6 JXTA

JXTA is an open-source P2P project, initiated by Sun Microsystems in 2000, providing a standardized and platform independent P2P platform [14]. The system is based on XML[1] messaging through employment of six protocols. Any piece of Internet connected hardware implementing these protocols, or a subset of them, can participate in a JXTA network. Nodes on the JXTA network are called peers. Peers form peergroups, based on common interests and goals, within which the participants share resources [11]. The JXTA platform provides a rich set of P2P features, thus simplifying the development of distributed systems.

3 COMPUTER SUPPORTED COLLABORATIVE M&S

3.1 Computer-based collaboration and M&S

Since the science and hype of Virtual Reality (VR) broke through, huge interest and activities have been conducted within the field. Despite the interest and future-thinking about the area, 3D virtual worlds have not yet reached into our offices and everyday lives. VR is instead a part of the larger field of using computers to support human-human collaboration, an area which has gained far more usage than VR in itself, due to its availability and range of technical possibilities. Groupware, videoconferencing and shared project areas are just a few of the kind of products used for these purposes. Computer-based collaboration can assist in joining people and organizations in the same environment, allowing people to share not only resources but also work areas, tools and environments. Though computer-realized collaboration may never represent a substitute for real human-human work, it can be used for bridging distances and increasing and facilitating cooperation.

These advantages are applicable within other areas as well. If considering collaborative M&S, sometimes referred to as CMAS, it could help joining people like software engineers, VV&A expertise and others in a common computer environment. With CMAS a project team could cooperate on M&S problems, with immediate support from SMEs, and with the customer supervising the activities, no matter if they are located on the same place or not. This improves and assures quality of work and enhances work efficiency. Within the defence in general, computer-based collaboration is a very interesting issue, since often military personnel are spread over long distances. A key feature here is the possibilities of increasing the availability of competence and expertise, an issue which could be of considerable importance within critic systems for C3I and other domains.

3.2 Infrastructure for CMAS in NetSim

One of the main goals of NetSim is to provide support for collaborative work. If complying with the definition of Collaborative Virtual Environments (CVEs) as described in [16], a CVE shall provide shared information, tools and communication access, and need not provide a 3D visual environment. The work of NetSim focus on constructing an every-day used defence environment, for practical collaborative M&S, which is why we dismissed the thoughts of flashy 3D worlds and emphasized on reducing complexity and enhancing availability instead. This increases the possibilities of integrating the infrastructure in already existing systems, such as for example C3I systems. Thus a flexible and lightweight infrastructure for CMAS was designed. A first prototype has been implemented and integrated within the NetSim environment. It mainly constitutes a middle layer, between a Java GUI[2] and the JXTA P2P network, and is

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[1] *The Extensible Mark-up Language (XML) is a mark-up language designed to describe and encapsulate data. It has become a major technique for exchanging data in heterogeneous environments, since it provides a platform and programming language neutral data format [15].*

[2] *GUI – Graphical User Interface, the visual application in which the user interacts with the environment.*

based on two components. The first component is a core, the Collaboration Core (CC), containing functionality for collaborative work, implemented using P2P technology. The second is an HLA coupling that provides means of collaborative simulation, and is implemented on top of the CC. These are further described below, and were describes in detail in [9].

3.2.1 Collaboration Core

The CC allows users to collaborate on M&S activities, or any kind of activities that the environment supports. Currently it provides, among others, functionality for creating, searching for and joining collaboration groups[1]. The collaboration groups are based on the concept of JXTA peer groups, and are used for grouping collaboration participants and for utilizing group functionality and mechanisms for managing collaboration (described in 3.3). A group provides group specific settings and information, and specific services and tools that may be used (collaboratively) within that specific group. The tools can be anything from communication means, such as text chats and web-cams, to advanced M&S or other tools. The infrastructure allows for further extension and integration of tools but, as mentioned before, it is currently just a prototype. The tool that is demonstrated and used today is a simple shared graphical tool, in which users may collaboratively compose HLA federations out of HLA federates. Users cooperate through using communication tools such as chats and web cams. In the current application, a chat is provided within the application and a web cam is used externally. The CC allows participants to share views, meaning that all see the same thing at the same time within a work area or tool. Hence, they see the same actions and changes at the same time, similar to sharing tools over a network, but in a decentralized way through using P2P technology (JXTA).

3.2.2 HLA coupling

The second prototype component is the HLA coupling that supplies the user(s) with a graphical interface in which the result of the distributed simulation is visualized. All participants in a group see the simulation and the same states of the simulation at the same time. This feature is implemented using the HLA framework rather than based on P2P technology, for reasons discussed below. Users may stop, play and step-forward the simulation, and all group participants receive the same new states if the simulation is changed or interacted with. This demonstrative collaborative simulation can be of considerable use for military planning, distance education, strategy demonstration, or when using M&S as basis for decision support etc.

3.3 Challenging issues and implemented solutions

During the work some challenging issues were identified that exist within collaborative systems, and which are naturally common for most distributed systems [17], such as mechanisms for maintaining information consistency and fault tolerance. It is challenging to synchronize and coordinate actions and interactions within a group, i.e. to guarantee that all participants have the same common picture at the same time, and that no changes or actions on the same object collide. Another issue was the (collaborative) simulation, since different platforms demand various solutions for the same visualization. This requires generic interfaces for simulation and tools, which comply with the computer capacity and properties in use, problems that are not fully addressed in current work. Moreover network properties may constitute a problem due to delays and overhead, another issue not covered yet. Challenging issues that are currently considered are presented in brief below.

3.3.1 General infrastructure for collaboration

Designing an infrastructure for collaborative work in an efficient way, which is extensible for integration of new functionality, is not an easy thing. A usual procedure is to employ a server-centric solution, where

[1] *A user can be a member of any number of groups.*

the server (or central computer) propagates screen-dumps[1] of a shared work area (may be a tool) to all participants. This is used by products such as VNC[2] and NetMeeting[3] and can be easily applied but is inefficient due to overhead among other things. Our implementation (the CC) provides a more optimized solution that is principally distributed and that considers changes in objects' states, and transmits the state changes only, to all participants. On the other hand our solution sets high requirements for integration of new tools into the infrastructure, which may have to be generalized in future work.

The distributed infrastructure was implemented using built-in group functionality in the P2P framework JXTA [14]. A new kind of group was created, the CollaborationGroup, which is an implementation that extends the group concept and includes services for group functionality etc. When a new group for collaboration is created, a new such group is started, instead of an ordinary PeerGroup. When joining a collaboration group users receive a handle to a shared communication channel. Thus, all actions produced within a group are propagated and managed along this channel.

3.3.2 Coordinating participant actions

Collaborative modelling requires real-time interaction. The actions produced must be coordinated and synchronized among the participants. For this we applied a coordinator-based scheme, which is a widely used solution to the problem. A coordinator represents the node through which all actions are passed and coordinated. When a user wishes to perform an action on an object in the shared area, it requests the coordinator for permission. If no other user wants to act upon the same object, the request is processed immediately and all users receive the new shared state, without causality errors or action conflicts. This results in a temporary centralized solution, which is easily implemented but not optimal if a lot of information has to be coordinated. Coordination and synchronization would rather be managed in a distributed fashion (more complex). Our solution also brings that client synchronization is managed immediately, rather than when it is necessarily needed, i.e. when users need to have the same views. If all participants' views are coordinated only when needed, a better and more scalable implementation would be achieved. Thus, these two issues are of concern for current and future work.

3.3.3 Synchronizing collaborative simulation

Collaborative simulation does not require such frequent coordination of interactions as other M&S activities do, since the user interactions during simulation are most likely simple ones such as stopping or pausing the simulation. Thus coordination is not an issue here. In contrast, a high amount of simulation information needs to be transmitted to and synchronized between the users, in order to guarantee that all users see the same state of the simulation at all times. This means that it may not be possible for the information to be continuously synchronized due to the overhead and time delays it may cause. In current implementation, the clients' views are synchronized continuously (synchronously), and would preferably be exchanged with more efficient solutions. The issue of effective synchronization was highlighted in previous work [9], and is an important part of current work (discussed below).

3.4 Synchronizing collaboration participants using HLA

When implementing functionality for collaborative simulation, the design choice was made to use HLA instead of JXTA for synchronizing participant visualization and user interaction in the simulation. One of the reasons was that HLA provides excellent functionality for time management and means for federation synchronization [20]. The HLA coupling was implemented as a layer on top of the CC, as mentioned above. Each user application comprises HLA functionality, which acts as an HLA federate, called the Visualizer federate. The Visualizer subscribes to the simulation objects and attributes necessary for

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[1] *Screen-dump = a momentary image taken of the screen.*
[2] *VNC – Virtual Network Computing is a free product for sharing work areas [18].*
[3] *NetMeeting is a product that allows projects to use shared work areas and tools [19].*

visualizing the federation, in order to illustrate the accurate simulation result in the client's window. The Visualizer federates, i.e. the clients' views, are synchronized using HLA built-in mechanisms. User interactions with the simulation are handled through the Visualizer and are forwarded to the rest of the federation. An HLAManager[1] reflects the interaction event, and makes sure the proper action is processed, as for example pausing the federation or stepping it forward. Federations used today are based on time-stepped federates and the synchronization is performed synchronously in fixed time intervals. This is neither efficient nor scalable, since it results in a great number of synchronization points, no matter if anything important has occurred or not. This may in turn cause time delays and unnecessary overhead.

In order to investigate more efficient ways of synchronizing the federation for our purposes, current work emphasizes on facilitating the use of time management (TM) in HLA. A middle layer on top of the HLA/RTI is being designed and implementation of it has been initiated, which is somewhat similar to approaches made such as [21] and [22]. The layer is included and utilized in each federate, and comprises functionality for TM and various synchronization protocols[2]. A schematic view of this is presented in figure 3.1. Protocols that are intended are first of all simple solutions for synchronous and conservative simulation, but optimistic protocols are also considered. The layer is designed to relieve the simulation developer from some of the HLA specific logic. It will also provide various ways of synchronizing federations and estimating performance, which allows flexibility of synchronization protocols. It is intended to support us in evaluating and implementing efficient synchronization for the collaborative infrastructure, but can be of use within other areas as well.

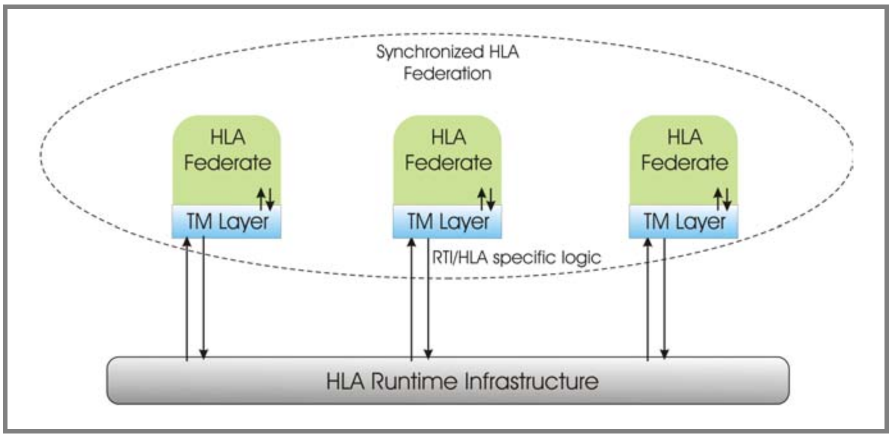

Figure 3.1: Schematic picture of middle layer for RTI/HLA specific logic.

3.5 Conclusions

Applying JXTA P2P functionality for coordinating and supporting collaborative simulation modelling turned out to be a good solution. The concept of JXTA peer groups and functionality for groups such as membership, authentication, group services etc. was very beneficial within this context. The group concept was extended, and gave us the result desired. But JXTA was by the time of work not a fully complete technology[3], and was not very easily managed.

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[1] *The HLAManager is used for facilitating some functionality within a federation, such as controlling synchronization and managing the federation. This is not crucial and everything may be carried out within each federate instead, but it facilitates federation development.*

[2] *The middle layer is nothing necessary, but it facilitates working procedures, user flexibility and provides extra functionality.*

[3] *The latest version of JXTA is 2.0, a version which the authors of this paper have no practical experience of yet.*

For the collaborative modelling a centralized coordinator-scheme was used. Since this solution is not scalable or efficient, it can be done more efficiently in a decentralized way. This issue is considered in current work. Also, the design to use optimized information flows (instead of screen-dumps) proved to be good.

For synchronizing and visualizing the collaborative simulation the HLA framework was applied, something that proved useful but needs to be extended regarding flexibility and ease-of-use. Synchronizing the federation synchronously showed non-efficient, and an alternative solution is currently designed which constitutes a flexible middle layer between HLA and the federates.

During the work it was pointed out that CMAS can be of considerable use within the defence, such as distance education and military planning. This holds for activities that use M&S as basis for decision support and situations when presence of SME:s may not be physically possible, but highly desirable etc.

4 RESOURCE MANAGEMENT

4.1 Resource Utilization for Distributed Simulations

As part of the NetSim environment, a module for execution of HLA federations has been developed based on the JXTA P2P platform, described in section 2.6. The main idea of this module, the Distributed Resource Management System (DRMS), is to utilize idle processing capacity in a network of workstations for distributed simulations. Furthermore, it should provide a distributed repository for storage of simulation components and associated documentation. Other projects have explored these possibilities, see for example [23], but then often based on the client server model for management of resources and storage of simulation components.

The basic idea of the DRMS is that desktop owners within an organisation download and install a small client that under certain circumstances share resources with other connected nodes. There are currently three levels of involvements for connected nodes. First, a node may share computing capacity for execution of HLA federations, referred to as a *computing resource* in the following text. Second, a node can be part of the distributed repository for sharing of content (HLA federates, documentation etc.). Finally, a node may share both computing capacity and content. The desktop owner always has the option to withdraw its involvement by changing a switch in the user interface or by closing the client. Therefore, the availability of resources on the network is expected to change fast and unpredictably in an Ad-Hoc manner. To comply with this the system includes mechanisms for migration, or movement, of federates between available computing resources during a federation execution. Furthermore, the dynamic characteristics of the network calls for redundancy (replication) in storage of simulation components to gain access to the same set of federates at all times. However, this part of the problem has not yet been fully addressed in the current implementation.

A major aspect to consider when implementing any type of P2P based system is discovery and matching of resources. The first problem relates to the basic strategy used to discover the presence of other nodes/resources on the network. Another problem to handle is how to identify those resources that match certain requirements.

The JXTA platform, and thus the DRMS, supports three different mechanisms for identifying nodes/resources, these are [24]:

- *No discovery* – using this approach, nodes rely on a cache of previously located advertisements that describe the features of resources. This is implemented by broadcasting advertisements from nodes at regular time intervals

- *Direct discovery* – in this case the nodes do not publish any advertisements until they are asked to do so, i.e. until a consumer of resources broadcasts a resource request on the network. This strategy is often referred to as flooding
- *Indirect discovery* – using this approach all nodes publish their advertisements to a centralized catalogue. The consumer node locates resources by requesting the catalogue. However, when a consumer has identified a producer, the communication is performed directly between involved parties

We have not yet performed any measures of the performance of these three approaches, but this will be addressed in future work, where also the new JXTA 2.0 release will be taken into consideration.

When suitable resources have been identified by consumer peers, the requirements of the requests have to be matched against the features of available resources. At present, the implementation includes simple mechanisms for this activity. First, the SOMs[1] of selected federates are automatically matched to assure simulation interoperability. Then federates are mapped to available computing resources i.e. nodes among the list of available resources are selected and assigned jobs to execute the federates. The advertisements of computing resources contain node specific information, for instance running hardware, software etc. Using this information, nodes running the fastest processors are chosen to execute federates. For a more technical description of the DRMS see [10].

The present approach of matching simulation components to form simulations and mapping individual components to computing resources is rather rudimentary. There is a need to enable matching of simulation components, not only at the architectural level (matching of SOMs), but also at a higher level. Furthermore, it is also important to describe a simulation component in terms of its requirements on the execution environment, and likewise describe the features that a computing resource provides for a simulation component. This calls for a better way of managing meta-descriptions of resources within the NetSim environment, to facilitate efficient searching, matching and execution.

4.2 Describing Resources

This section gives an overview of ongoing and future research topics, aimed at extending the support for metadata in the NetSim environment. The employment of meta-descriptions of resources within the NetSim environment is especially pronounced during three activities; searching for simulation components, matching simulation components and during execution of simulations. The role of metadata also differs greatly between these activities, which will be explained below. However, there are no solid boundaries between the uses of metadata in these activities. Certain types of metadata may be applicable in all three cases.

4.2.1 Searching for components

In this activity the user/users of the NetSim environment searches for available simulation components or previously assembled simulations. The basic requirement on metadata supporting this process is a well defined class structure, identifying subclass/superclass relations. This enables simple queries like "all airplanes" or "all fixed-wing aircrafts", which yields all components which are subclasses of airplane or fixed-wing aircraft respectively. However, note that this classification is not equal to the implementation related object class structure. Furthermore, the components should be described in terms of a system-of-systems view where, if applicable, a component's relations with other components are defined. For instance describing that system A and system B may integrate to form the superior system C. Finally, the

[1] *SOM is the short term for "Simulation Object model", and is the documentation and definition of a federate's all characteristics and possible interactions etc.*

metadata infrastructure should support descriptions of roles or capabilities, which enable searches in the form of “air based transportation” or “underwater surveillance”.

4.2.2 Matching components

This activity represents the attempt to compose simulations out of a number of components, i.e. component based development. This area is sometimes labelled *composability* and has been investigated extensively to promote model reuse and interoperability. According to [25] composability is

> *“the ability to combine and recombine components into different simulation systems for different purposes.”*

Irrespective of matching at the simulation architectural level, for instance matching of SOMs in the case of HLA, an environment supporting component based simulation development should include extensive metadata. This is to guarantee the composition of valid simulations at all levels. [26] outlines some of the fundamental requirements on metadata to support composability, namely;

Information about the model as a software component:

- Programming language
- Communication protocol
- Location of component

Information about the model as a simulation component:

- Spatial resolution
- Aggregation
- Temporal resolution
- Fidelity
- Required services

4.2.3 Executing simulation

This final activity involves mapping simulation components to computing resources prior to and during federation execution, i.e. assign jobs to various nodes in the network. Metadata that should support this process include running hardware and software on the computing resources and a set of requirements imposed by the simulation components. These requirements consist of information such as; what platform is needed to run the component? Is a specific runtime-environment needed to run the component? How computing intensive is the component? etc. Note that this process is not only required prior to the execution. Since the allocation of computing resources is not static, it is necessary to perform rescheduling from time to time.

4.2.4 Metadata framework

In order to create a foundation (or framework) for metadata, to support resource consuming systems (M&S and C3I systems) in various ways, a number of components are required:

- *Meta-language* – formal semantics and syntax, expressing shared and common understanding of a domain
- *Metadata repository* – supporting uploading/downloading of metadata through standardized

protocols (http, SOAP etc.), consistency checking and version control

- *Query language* – supporting complex queries on the metadata

Figure 4.1 outlines a conceptual view of a framework for metadata supporting efficient searching, matching and execution within the NetSim environment. The central component of this system is a repository where the descriptions of resources on the network, simulation components, data and computing resources are stored. The resources should be annotated according to a standard for data representation augmented with the shared knowledge of the domain. Activities within the NetSim environment are then supported by extraction of meta-descriptions from the repository, followed by semi-automated reasoning using the knowledge expressed by these descriptions

There are a number of efforts that could provide a basis for our envisioned metadata framework, for instance the Resource Description Framework (RDF) [27], the Web Ontology Language (OWL) [28] promoted by the W3C [27] or the DAML-S initiative, supporting semantic mark-up of Web services [29]. These approaches support the creation of specialized schemas, to represent the knowledge within a domain, which are used to describe various resources on the Web. There are also several efforts within the semantic web research community that build on these concepts to provide frameworks for meta-data driven solutions. Work has been carried out to support RDF based metadata in JXTA, including query, replication, mapping and annotation services [30]. Several other projects have constructed dedicated RDF databases with support for various RDF query languages, se for example [31] and [32]. The features of these approaches are diverse, ranging from stand-alone to distributed databases or P2P-style systems.

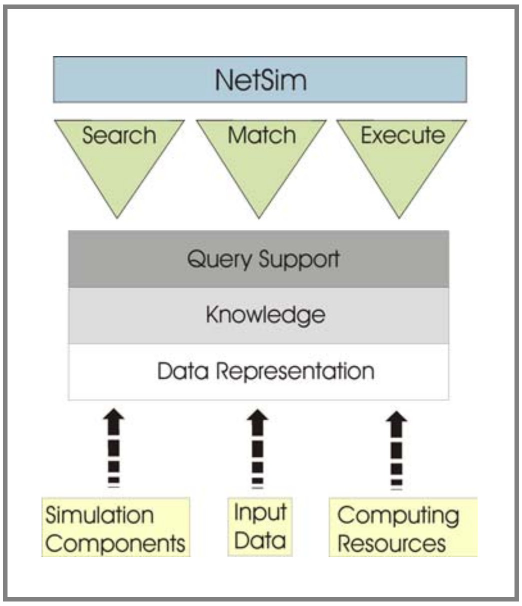

Figure 4.1. Conceptual view of a proposed framework for metadata enabling efficient searching, matching and execution within the NetSim environment.

4.3 Conclusions

From our experiences developing the DRMS we consider the lack of supporting metadata within the NetSim environment is of major concern. The support for meta-description of resources within JXTA in general is relatively weak, mainly key-word based searches of resource advertisements. We envision a layer on-top of JXTA supporting more complex descriptions of resources derived from a shared view. The meta-data layer should support the users of NetSim in simplifying identification and matching of resources as well as for optimization of the federation execution. We consider that the work carried out within the semantic web community is of great interest in this respect. Concepts from this area could be applied to model knowledge and provide extensive meta-descriptions of resources to enable automatic/semiautomatic localisation, selection, composition and execution of various resources.

5 SUMMARY & CONCLUSIONS

At the Department of Systems Modelling, Swedish Defence Research Agency, ongoing research is targeting the role of network/web based technologies in M&S, to support defence communities in their work. During the first phase of this research, focus has been on efficient resource sharing and means of computer collaboration. A prototype, named NetSim, has been implemented to investigate and demonstrate these issues, based on the open-source Peer-to-Peer platform JXTA. The NetSim prototype allows people at disperse locations to collaborate in creating various HLA simulations in a component-based manner. Executions of the assembled simulations utilize idle processing capacity of desktops currently connected to the system. As the NetSim is based on Peer-to-Peer concepts, and not dependant on a single server or desktop machine within the network, the system is to some extent more robust and fault-tolerant than a client-server solution. However the synchronization of collaboration participants is partly based on centralized control, which proved non-efficient and non-scalable. JXTA was at the time of implementation not a fully mature technology, which affected the overall performance of NetSim to some extent. For example, it lacks of support for extensive meta-descriptions of available resources on the network. However it should be pointed out that JXTA provides a rich set of P2P features, suitable for implementation of distributed systems such as NetSim. Future research will address distributed algorithms for synchronisation of collaborative work and a more flexible and extendable approach to resource management.

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Bridging a BMS and a CGF System using XML

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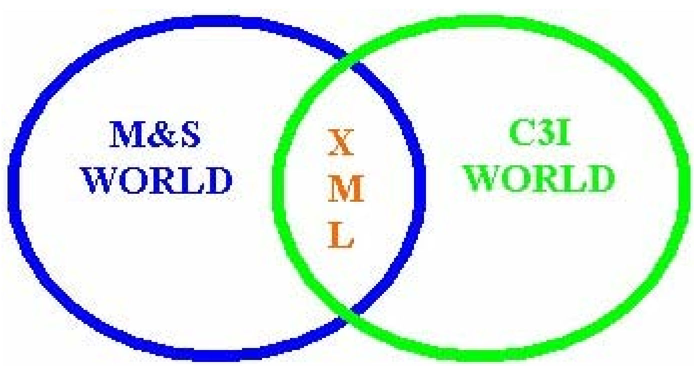

ABSTRACT

This paper presents part of the work that is performed internally for INTRACOM Defense Department. As an integral part of this work, a Battle Management System (INTRACOM iBMS) and a Computer Generated Forces System (produced by INTRACOM for this purpose) are linked together. As an example of *Lessons learnt from past experience in linking M&S and C3I*, the paper discusses the approach that was used to connect the two systems.

Paper presented at the MSG-022/SY-003 Conference on "C3I and M&S Interoperability", held in Antalya, Turkey, 9-10 October 2003, and published in RTO-MP-MSG-022.

BACKGROUND

The goal of the performed work is to demonstrate the capability to couple a Command and Control system together with a CGF system. There are two perspectives on the usefulness of this. From the ***CGF point of view***, the use of a C3IS as an interface device, optimizes the workload of the instructors and animators of tactical environment. It also reproduces current operational environment especially for training audience.

From the ***C3IS point of view***, interoperability with a CGF can offer new intelligent services in war-gaming and planning, reducing the need for cumbersome pre-battle group-working sessions.

Simulation systems can stimulate the C2 system by providing data that simulates the 'real-world'. This information now appears to have been received from peer C2 systems. In this way a simulated COP (Common Operational Picture) is created that is based on a simulation scenario. Applications of this technique are: assessment of C2 systems (performance, user interface etc.), assessment of C2 operator capabilities or training of C2 operators.

The simulation can provide the C2 operator with operational decision support by executing 'what-if' scenarii. Simulated systems can be 'initialised' from the existing COP in the operational C2 system and a simulation run can be started based on this information. The simulated scenarios supports the operator in his decision making process (e.g. mission planning or assessment of alternative COA's).

Simulations can assist the C2 staff in understanding the prepared mission plan (mission rehearsal) and refining the plans before the operation is executed. Commanders will be able to identify the aspects of the plan that will be crucial for success or failure.

Furthermore, new or experimental parts for an existing C2 system can be evaluated before purchase or even before full development by replacing an existing component of the C2 system with an embedded or external simulation.

Speech recognition/voice synthesis techniques has been taken under investigation as alternatives for sending/receiving commands/reports/acknowledgements.

C3I System

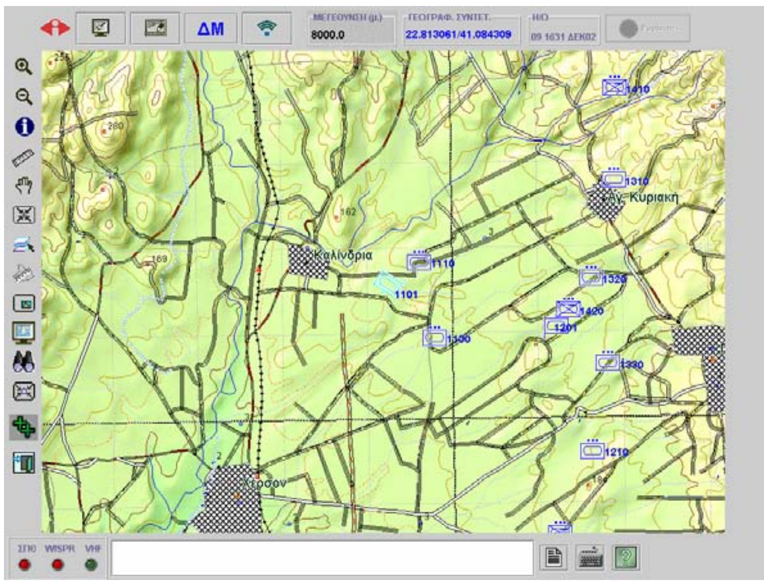

Figure 1 A screenshot of INTRACOM BMS

The most fundamental function of the C3I used (namely iBMS) is to provide the tactical picture to the commanders (all levels) and the driver. A map is displayed, containing dynamically changing geo-registered information, about everything that concerns the specific user.

Tactical Situation Update utility, allows users to manually refresh the tactical picture of the entire battalion, through a number of mechanisms. This has only to do with information regarding the enemy forces.

Logistics functionality is the function providing information about vehicle's systems, ammunition, fuel and personnel information. This function is also valid for echelon commanders, where the logistics of the respected echelon can be viewed.

C3I also provides Tactical planning. An echelon commander can study a plan received from his superior officer (next level in command), create his\her own plan and send it to his subordinates.

Finally, communication facilities allow messaging with other vehicles, control of transmission media etc.

BMS advantages

Using conventional techniques, i.e. war-gaming in order to elaborate the Operations Order, is a very cumbersome process. Imagine a couple of vehicles moving next to each other and setting a tent to accommodate all the involved parties. They form, what is known as a 'cluster'. In that cluster, the involved parties draw alternative plans on thin layers of film, positioned on top of the paper map.

With INTRACOM C3I (BMS) we get a completely different situation. First of all, there is no need to form any physical clusters any more, that on top of everything else they can be easy targets for the enemy. Each involved party can take part in this group-working process remotely, through the use of the BMS. The BMS offers a 3-dimensional view of the map, allowing navigation in all directions. The user can select ego-centric and exo-centric views. Of course, whatever was possible on a 2-D map is still possible to do with the 3-D view of the map, like measuring distances, determining Line Of Sight (LOS) etc. Each individual party involved in the war-gaming exercise, places his units and he can move them or delete them to elaborate on the Operations Order. The other involved parties can then see the move of the first player and respond with their moves. It is something like playing chess or bridge on the internet. Of course, all this can be recorded as a scenario and played back whenever it is needed.

How CGF comes into the game?

However, not everything can be dealt efficiently through this group-working process. There are situations, where real expert play is required. There may be a need for additional dimensions of the situation to be considered, like for instance messages to be exchanged or logistics situations during the game. Then, an opponent like the computer might be used to war-game with. This time, the metaphor is simply like playing chess against the computer.

In order to get intelligent behaviour like this, the use of a Computer Generated Forces (CGF) or more generally speaking of a simulation federation, was preferred. How to do that however?
There are various challenges.
First of all, both systems (the BMS and the CGF) should run on the same single computer of a vehicle. This is not as easy as it looks. Keep in mind that it is very possible to deal with military equipment that needs to meet the toughest environmental standards. Such hardware must be able to survive in temperature ranges like -40 C to +70 C, making us think about what happens to the operator at that time. It should come to no surprise then, that the performance of such hardware is not really state-of-the-art and therefore, hosting a BMS and a CGF application at the same time needs at least some attention.
Secondly it is clear that there must be a way to interface the two systems. As something like this is not available today, it was obvious that an interface should be developed. But before thinking about the right interface approach, we should consider the requirements to build an interface. Luckily, at INTRACOM, problems like access to source code or documentation weren't met, as there is a number of small-scale in-house CGF systems, in order to be used for tests together with the BMS. Furthermore, XML packages are numerous and free for usage.

Introduction to XML technology

XML is a meta-language that supports the customized definition of the components of a language (syntax, data types, vocabulary, and operators) needed to support the interchange of data for a particular application environment. XML provides a basis for the development of data transmission formats that are transmitter and recipient independent and that can be completely self-describing and self-contained. These inherent XML capabilities permit federates to be added to a federation with a minimum of software development and with high confidence that information exchanged between federates will be accurately represented, transmitted, and received within the federation.

XML permits the simulation community to move to a deeper level of specification by providing data definitions and formats that are flexible, independent, and comprehensive.

Extensible Markup Language (XML) can make its contribution to distributed simulation by providing an interoperable and open format for data representation and be of special use in the development and maintenance of computer-generated actors (CGAs).

Each application-specific definition is contained within a Document Type Definition (DTD). The DTD describes a vocabulary and syntax for the data (document) to be transmitted. XML provides a basis for the development of data transmission formats that are transmitter and recipient independent and that are completely self-describing and self-contained.

Why XML?

Several factors indicate that XML will continue to grow in popularity and usage. *First*, XML is a flexible approach to formatting documents. The XML capability to define and use custom tags and the minimal requirements imposed by XML on the markup language being designed give us great confidence that we can express the transmission format robustly within the boundaries of the language. *Second*, XML is widely used and is standardized; therefore, the basic components of the language are stable and well understood.

Third, XML is precise, it has a well defined set of rules for describing a document containing the markup components and for ordering the contents of a document but does not specify semantics. As a result, XML provides the basis for developing a common data format that is robust in the face of data corruption, self-describing in terms of tag meaning, and extensible to accommodate unforeseen data requirements.

Fourth, because XML supports the definition of custom tag-sets and custom document structures that are completely contained within the document, an XML-based specification for CGA state can be automatically searched and categorized by computer programs instead of manually.

Fifth, XML provides interoperability between different platforms.

Finally, XML supports the creation and use of multi-part, distributed documents and supports interchange of data between applications.

Approach followed

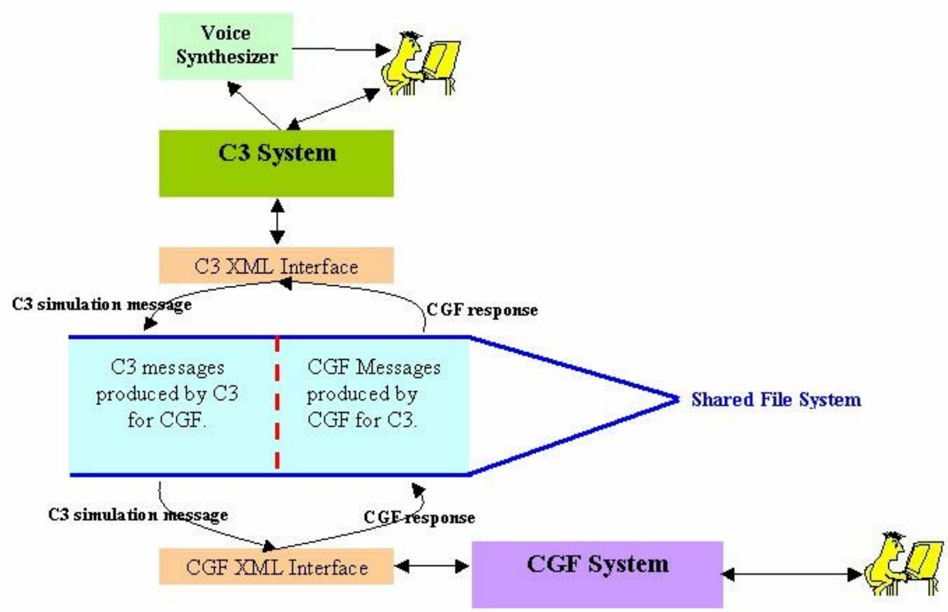

Figure 2 XML Approach for interfacing C2 world and CGF world

Technically speaking, the purpose is to connect a C3I operator to a constructive simulation. Both systems agree on common XML formats that should be "exchanged" (each system has to understand what the other has sent) and on common content (vocabulary). Vocabulary means the possible types of messages that are going to be used in a scenario. Messages like 'Move order', 'Logistics report', 'Situation Report request', 'Order Of Battle' etc. are agreed upon. The set of messages handled by a CGF is of course, only a subset of those of a BMS, as they do not include free text messages.

The *data flow* between the C3IS and the CGF relies on *XML* technology. The components addressing this interface share a common directory (using File System, eventually mounted in case of different machines), writing and/or reading XML files that depict messages that are being exchanged.

A synchronization-pool mechanism (see Figure 2) is used. Both systems agree on the directories that they shall be shared.

- o One directory (let’s call it C3_dir) is used by C3I system to write its commands. CGF reads from this directory.
- o One directory (let’s call it CGF_dir) is used by CGF system to write its reports to C3I. C3I reads from this directory.

A semaphore file is used. When an application (C3I or CGF) wants to read/write from/to a directory it first checks for a semaphore. If the semaphore is there, then the application removes the semaphore, does its job (writes new files/reads files) and then puts the semaphore back to make the directory usable by the other application.

The main advantage of this solution is to ensure generic and device-independent simulation messages in order to support information coming from and going to the two interfaces that were used; the command and control system and a vocal interface. The two interfaces (from the CGF point of view) are independent one from another and each remains functional without the other. This allows to easily build scalable and multi-level systems and to deploy them depending on the training needs. Both interfaces define some requirements on this CGF in order to ensure consistency between requirements addressing CGF. As the intermediate XML layer controls the data entities and ORBAT of all involved sides, it is possible that the C3IS initiates the loading of those data. At the application level, that means that the C3IS is capable of playing what-if scenarii without the need for war-gaming sessions involving a number of human operators.

Types of exchanged messages

Here is a list with the type of messages that are exchanged during interaction between the two systems:

- ***C3I to CGF***

- C3I can request a “Logistics Report” from unit or group of units.
- C3I can send a “Move” order to a group of units (company/squadron/platoon/etc.) with information about waypoints that must be followed, type of formation and speed they should keep.

- ***CGF to C3I***
  - CGF sends an “Acknowledgement message” for each command it receives from C3I.
  - CGF sends a “Logistics Report” for the unit or group of units from which C3I requested information.
  - CGF may send “Enemy positions report”.
  - CGF may send its ORBAT (OR of BATlle), so that C3I to be able to update the units representation on its map.
  - CGF may send “Under Attack” for each of the units that are under attack by enemy forces.

C3IS enrichment

Utilization of Voice Synthesis/Recognition technology can enrich the C3I system

– A ***Voice Synthesis*** component could produce voice that corresponds to a received message. This would make the interaction between C3I-CGF look closer to reality. For example, when C3I receives an “Under Attack” message from CGF a voice could be produced like “Under Attack from 1112 unit”.

– A ***Voice Recognition*** component would be useful as alternative way of sending a command. E.g. the C3I commander could send a request for logistics report either using the graphical interface of C3I or through his/her voice (using the vocal part of C3I).

CONCLUSION

XML was successfully used on a C3I to assist the user in his decision making process and in understanding and refining mission plans.

Building such an interface using XML, a common format and content is required, as well as a way of synchronising the two systems.

The main advantage of this solution is that it ensures generic and device-independent simulation messages in order to support information coming from and going to the two interfaces that are used; the Command and Control system and the Voice Recognizer. The two interfaces (from the CGF point of view) are independent one from another and each remains functional without the other. This allows to easily build scalable and multi-level systems and to deploy them depending on the training needs. Both interfaces define some requirements on this CGF in order to ensure consistency between requirements addressing CGF. As the intermediate XML layer controls the data entities and ORBAT of all involved sides, it is possible that the C3I initiates the loading of those data. At the application level, that means that the C3I is capable of playing what-if scenarii without the need for war-gaming sessions involving a number of human operators.

The approach has proved to be fruitful as the communication between the C3IS and the CGF is successful using both the messaging and vocal interface.

The approach is proven definitely flexible and relatively easy to achieve.

However, it is an interface devoted to the specific pair of systems and cannot be reused for any selection of systems (namely the mechanism and its working parts are not like a template that can be used between a different C3I and CGF system).

Abbreviations:

BMS	Battle Management System
C3I/S	Command Control and Communication Information / System
CGA	Computer Generated Actors
CGF	Computer Generated Forces
COA	Courses Of Action
COP	Common Operational Picture
LOS	Line Of Sight
M&S	Modeling and Simulation

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Soldier System Information Interoperability

Abstract

This paper overviews the standardisation work being undertaken by NATO Topical Group 1, Soldier System Interoperability. The Group's work on systems analysis for dismounted operations is described, with special empahsis on the approach being taken to C4I. The rationale for the development of a STANAG to facilitate low-level tactical data exchange is also described, including an overview of the experimental and demonstration work being undertaken to inform STANAG development.

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NATO Topical Group 1

This paper has been prepared on behalf of NATO Topical Group 1 (TG/1) at the direction of the UK Ministry of Defence Future Integrated Soldier Technology (FIST) Integrated Project Team (IPT). TG/1 is a Level 2 Group and is concerned with soldier system interoperability. The Group is open to and attended by Partners. Australia has been granted observer status. The TG/1 objectives set by the NATO Armaments Advisory Group (NAAG) are as follows:

a. to develop STANAGs in 5 focus areas;
b. to foster information exchange on soldier systems;
c. to broaden and deepen interaction between groups in the NAAG.

Develop STANAG in 5 focus areas: These focus areas are as follows:

a. Power – a STANAG is currently being finalised, addressing dismounted soldier electrical supply systems.
b. Architecture – focusing on electrical interface and data protocols.
c. Clothing, equipment & protection – seeking to establish current standardisation work already underway within NAAG.
d. Weapons – a newly defined area of work.
e. C4I – concentrating on the exchange of low level tactical information exchange.

Foster information exchange on soldier systems: TG/1 brings together the nations with major programmes and those seeking to select solutions, or elements of the solution, from the 'major players'. Standardisation increases the potential to achieve this intent.

Broaden and deepen interaction between groups in the NAAG: TG/1's role is to ensure that work underway elsewhere in the NATO is focussed towards meeting the needs of the dismounted soldier. This implies the need to link with other relevant NATO Groups, where issues such as vehicle system interfaces and combat identification are being addressed.

TG/1 evolved from the former LG3 WGE3 and has a mandate to operate until Autumn 2004. Work under LG3 WGE3 included a task to provide guidance to the modelling and simulation community (principally

LG3 WGE4). As a predominantly User-based group with technical support, it was considered important to provide guidance to the modelling and simulation community to ensure that outputs were expressed in terms readily understood by the military. That work proceeded with a systems analysis of dismounted tasks and generated an effectiveness measurement framework with an emphasis on defining Measures of Effectiveness (MoEs) at the mission level. The focus was to ensure that the modelling and simulation community could focus its work and produce outputs to which TG/1 could relate. The work has been termed 'NATO measurement framework'.

As part of this work, TG/1 attempted to better understand C4I MoEs. The next section overviews the systems analysis conducted to identify MoEs associated with company level and below, before exploring our C4I-related analysis. The development of a STANAG to define data formats for low-level tactical data exchange is then described.

Low level mission analysis - overview

Analysis has been undertaken of dismounted operations, typically at Company level and below. Missions have been decomposed into component vignettes. Listed below are some of the component vignettes that have been identified for a mission 'to attack and hold an enemy position':

a. planning and preparation;
b. close target recce;
c. advance;
d. attack;
e. re-org;
f. defence;
g. re-org.

Collective Measures of Effectiveness (CMoEs) have been defined for each of these vignettes. As and example, the close target recce vignette could have the following CMoEs:

a. detection avoidance (Y/N);
b. consumables employed;
c. time taken (as in orders?);
d. casualties;
e. quality of information obtained (subjective);
f. physical and mental sate of soldiers employed (i.e. their ability to continue operations).

At the mission level, the CMoEs would be selected from those defined for the vignettes in the context of the orders set. Some of the vignette level CMoEs would become unimportant at the mission level and would not be employed (e.g. detection avoidance during close target recce). For the example mission, these could be:

a. own casualties;
b. other soldier's condition;
c. consumables;
d. achieving key event timings specified in orders.

The relative importance of CMoEs will vary according to the mission; e.g. the situation may determine that holding an objective for the specified time is more important than casualties suffered.

The measurement framework also indicates how the relationship between the soldier and his equipment within the physical and organisation environments contributre to providing a level of capability to undertke a task. Actual equipment Measures of Performance are thus modified to bring a certain level of capability with which to undertake a task. This is shown in Figure 1.

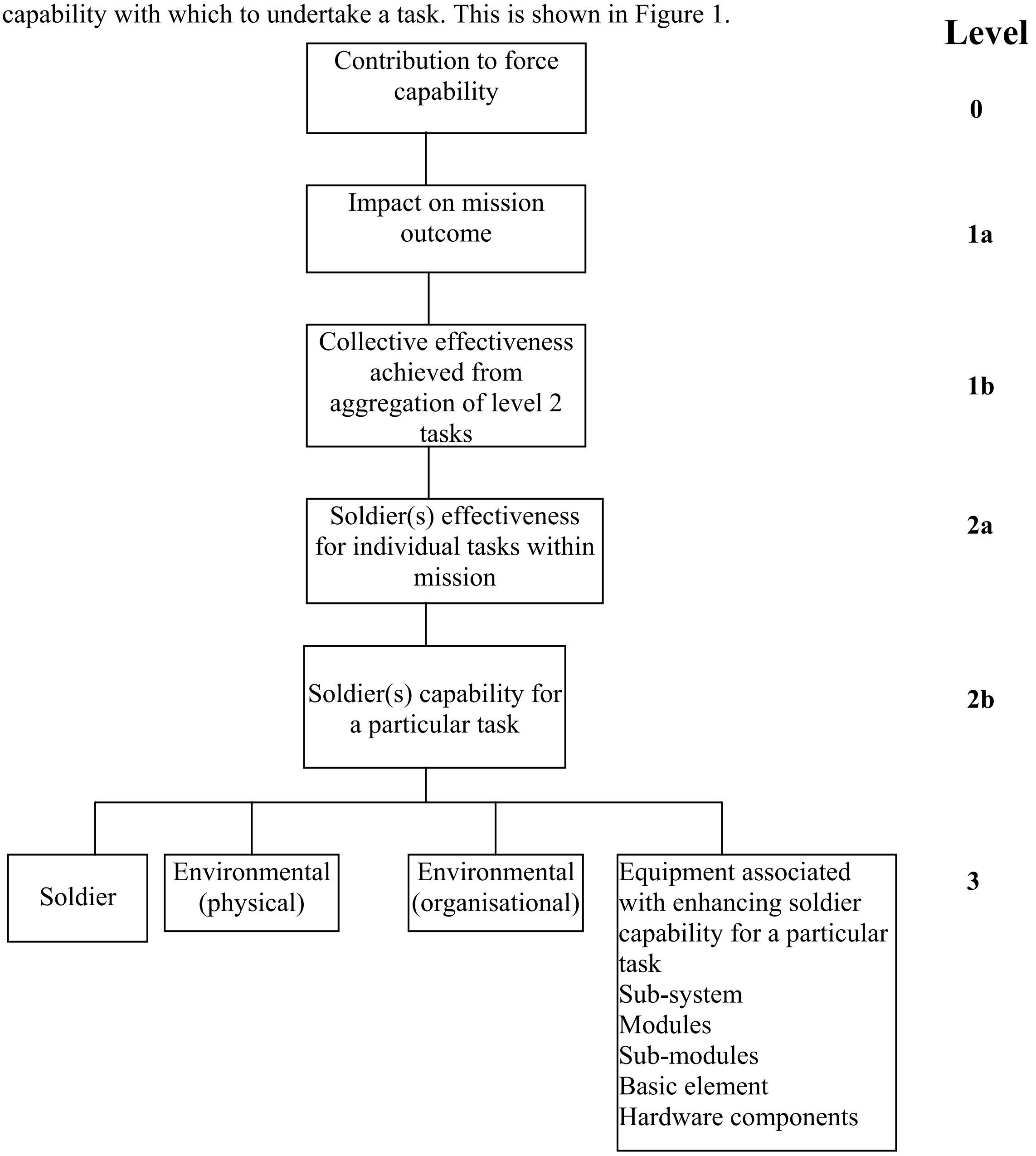

Figure 1: Measurement framework levels

Low level mission analysis – C4I aspects

The NATO measurement framework has established effectiveness principles relating to command and control (C2). If C4I equipment is to be evaluated, perhaps during field trials, then a data collection approach must be defined. Analysis has identified the following general C2-related capabilities:

a. the ability to receive and pass on orders prior to the start of the mission (*orders pre-mission);*

b. the ability to navigate (*navigation*);

c. the ability to achieve a level of direct situational awareness consistent with the needs of the mission (direct situational awareness);

d. the ability to achieve a level of indirect situational awareness consistent with the needs of the mission (indirect situational awareness);

e. the ability to provide an adequate post mission debrief (debrief);

f. the ability to operate covertly (detection avoidance);

g. the ability to adapt the plan as a result of changing circumstances that develop after the mission has commenced ('command agility');

h. the ability to achieve key event timings (key event timings);

i. the ability to re-organise the soldiers after the completion of the mission in a timely manner (reorganisation time).

Command agility

For all but one of the above capabilities, the MoEs associated can be defined with relative ease. Often, but not exclusively, the CMoE associated with C4I is time. However, C4I could actually make a mission longer, if a more covert route was established that allowed an enemy position to be taken by surprise. Here, the effectiveness of the C4I would derive from a reduction of own casualties.

The most challenging C4I capability to analyse was point g, "*the ability to adapt the plan as a result of changing circumstances that develop after the mission has commenced*". TG/1 have termed this 'C2 agility'. If a mission proceeded according to the original plan, it could be argued the actual conduct of the mission could have been completed *without the commander*. However, it is when unforeseen, or unpredicted, changes to the mission have to be managed that the commander, supported by C4I, must intervene. Qualitative assessment of the performance of C2 during such situations can be assessed, using a structure that seeks to analyse the C2 process when managing the situation.

Command agility analysis is conducted by applying the following questions to events that required commander intervention:

a. Did the mission go according to the original plan?

b. If not, what caused the need to deviate from the plan?

c. Was this change communicated efficiently to those concerned? Was the change implemented as intended?

d. Was the commander's situational awareness adequate when the change was defined?

e. If not, what information did the commander need and what would have been the best way of accessing this information?

f. Could anything be done to improve the way the change was implemented?

g. Did the change, as implemented, have a critical impact on the outcome?

h. Are there any other material factors that affected C2 flexibility?

After action reviews of UK C4I field trials, provided responses to the above analysis, from each commander. The technique has been used to establish effectiveness, both with current C4I and then with enhanced systems. Often it is possible to demonstrate that, when the re-direction was inadequately implemented, it could be linked either with the failure of the mission or reduced collective effectiveness. Although a subjective process, it does provide a basis for analysis of the effectiveness of C4I.

Analysis subsequently concluded that, when assessing the outcome of a mission, it was necessary to include a factor that related to the *degree of difficulty* imposed on the commander by external events that occurred during the conduct of that mission. Only in this way can C4I be accurately addressed.

The CMoE framework has been used extensively in national trials as a qualitative/quantitative mechanism to assess performance of capability. The work has been published by NAAG [1] but requires updating, following experience gained in its use on field trials.

Requirement for low-level tactical data exchange

This section of the paper addresses the TG/1 C4I team's work on production of a STANAG relating to data formats for achieving low-level tactical interoperability.

One might ask where the requirement is for sharing information at such a low level? There is no NATO requirement at present but the TG/1 C4I team is tasked with exploring the 'art of the possible'. It is then down to NATO to decide whether the capabilities offered will be employed. However, there is, at present, a high degree of force mixing within NATO operations. Dutch platoons operate within UK companies during peace keeping. Furthermore, the sharing of tactical information across force boundaries will provide an increase in situational awareness. This may well contribute to a reduction in the occurrence of potentially fratricidal situations. In exploring the art of the possible, TG/1 is establishing other associated challenges that must be met, particularly those related to security and radio bearers. These are listed below. There are other challenges related to NATO itself that are also being addressed. The key one is ensuring that TG/1's work does not duplicate work already being undertaken elsewhere within the NATO system. TG/1 aims to ensure that the data model that is being developed is correctly placed within the overall NATO data model. This is very complex and work has only recently commenced.

Approach taken to development of a STANAG for low-level tactical data interoperability

The tactical information interoperability STANAG is being developed in parallel with an experimental and demonstration programme. The scope of tactical data exchange would include:

a. positional data;
b. force boundaries;
c. positions of key features e.g. minefields;
d. text information;
e. lines of departure;
f. APP6a symbols.

Relevant tactical data needs to have been identified. Many of these are addressed in APP6a. The possibility of updating APP6a to include further types is being explored. TG/1 has listed all the symbols and related information that are of use to enable awareness sharing at the lower level. Many of these are covered by APP6a but some are not. These TG/1 is seeking to have included.

TG/1's approach has been to generate what can be termed 'the NATO data library'. This is a definition of how, in a country-independent format, tactical objects and their attributes should be described.

Example information includes:

a. co-ordinate (latitude/longitude as floating point, based on WGS84 datum grid).
b. object identity size (integer).
c. object identity (e.g. callsign as text).
d. object nation (e.g. UK as fixed text field of 2 characters).
e. date/time (e.g. DDMMYYhhmmss as fixed text field of 12 characters).

The STANAG does not intend to specify how an individual country will actually display an item of tactical data, if it does not wish to use it or finds that APP6a symbols are not suited to small scale electronic map displays. Where symbols have an APP6a identity number, that identity number defines the object in TG/1's approach and hence the reason an update to APP6a is needed.

Having defined how information should be described, it was then necessary to seek a format to send the information between one national system and another. This data definition is described using Backus-Naur Form (BNF). The definition, together with the object/attribute list, provides the basis for the creation of an appropriate interchange data reader and writer. This is what TG/1 has termed in the NATO library and this is a country-neutral definition.

For the purpose of the experimental programme, a NATO library code has been generated to suit three different operating systems used in the experimental and demonstration programme (WINDOWS 98/NT, WINDOWS CE and Linux).

TG/1 is linked with the International Collaborative Opportunities Group (ICOG), to further the achievement of low-level tactical data interoperability. The ICOG nations are UK, US, Germany, France and Italy, but all NATO nations and Partners are invited to joint TG/1 / ICOG experimental workshops. The NATO nations actively participating in the experimental and demonstration programme are Canada, France, Germany, Norway, UK and the US (Army and Marines). Some nations employ prototype systems, whilst others participate with research equipment. All use different map applications. Each nation has written a file that allows it to read from and write to the neutral format.

Experiments are conducted inside, with systems co-located around a table. The mechanism for exchange between national systems (for experimental and demonstration purposes) has been via WLAN 802.11b. The tactical information for exchange is generated within a map application layer (typically about 1Kb file size). The information therein is then written to the NATO neutral format and sent as an attachment to an e-mail, addressed to one or more nations participating in the experiment. On receipt, the receiving national system automatically opens the attachment, feeds the neutrally formatted information into its conversion program and then displays the received information correctly geo-referenced.

Progress in experimental programme/planned activites

Successful data exchange has been achieved between UK research C4I sets and C4I equipment from Canada, Norway and France and the US. The level of tactical information is superficial at this stage, but it is sufficient to establish and check principles. In 2002, using an earlier version of the library, the UK and Canada exchanged information by way of floppy disk. Figure 2 provides a typical example of successful exchange between the UK and Norway, both with different operating systems and map applications. The Norwegian system (left) displays UK tactical information and the UK system (right) displays both UK tactical data and that received from Norway. At a joint ICOG / TG/1 C4I meeting in Oslo in June 2003, exchange over WLAN was, to some degree, achieved between Norway, France and the US. Further experimental workshops are planned between writing and delivery of this paper. The TG/1 C4I team will provide a demonstration of tactical information interoperability to the full TG/1 meeting to be held in

Rome (22 October 2003) and to the NAAG in Autumn 2004. Other nations, including a Partner nation, are beginning to become active in the experimental programme. It is anticipated that the number of nations participating in the NAAG demonstration may reach ten. The experimental/demonstration programme has assisted greatly in de-risking the STANAG, scheduled for publication in Autumn 2004.

Challenges to achieving low level tactical data exchange

Clearly, establishing the formats for data exchange is a relatively straightforward task; actually achieving the tactical interoperability on the ground may not be so. Tactical exchange, in any ‘interoperable session’, is likely to be limited to just two nations, but this need not be the case. The challenges that the combined group is addressing include the following:

a. communications bearer;
b. security;
c. encryption;
d. unauthorised use of systems;
e. information conflict;
f. situating TG1's data model within the overall NAAG data model;
g. STANAG maintenance.

Communications bearer: With software programmable radios universally employed, exchange is, theoretically, ‘easily’ possible. The C4I team has been exploring the loaning of a radio to an adjacent force and has ensured the necessary interface information is embedded in TG/1 architecture STANAG should this the approach selected.

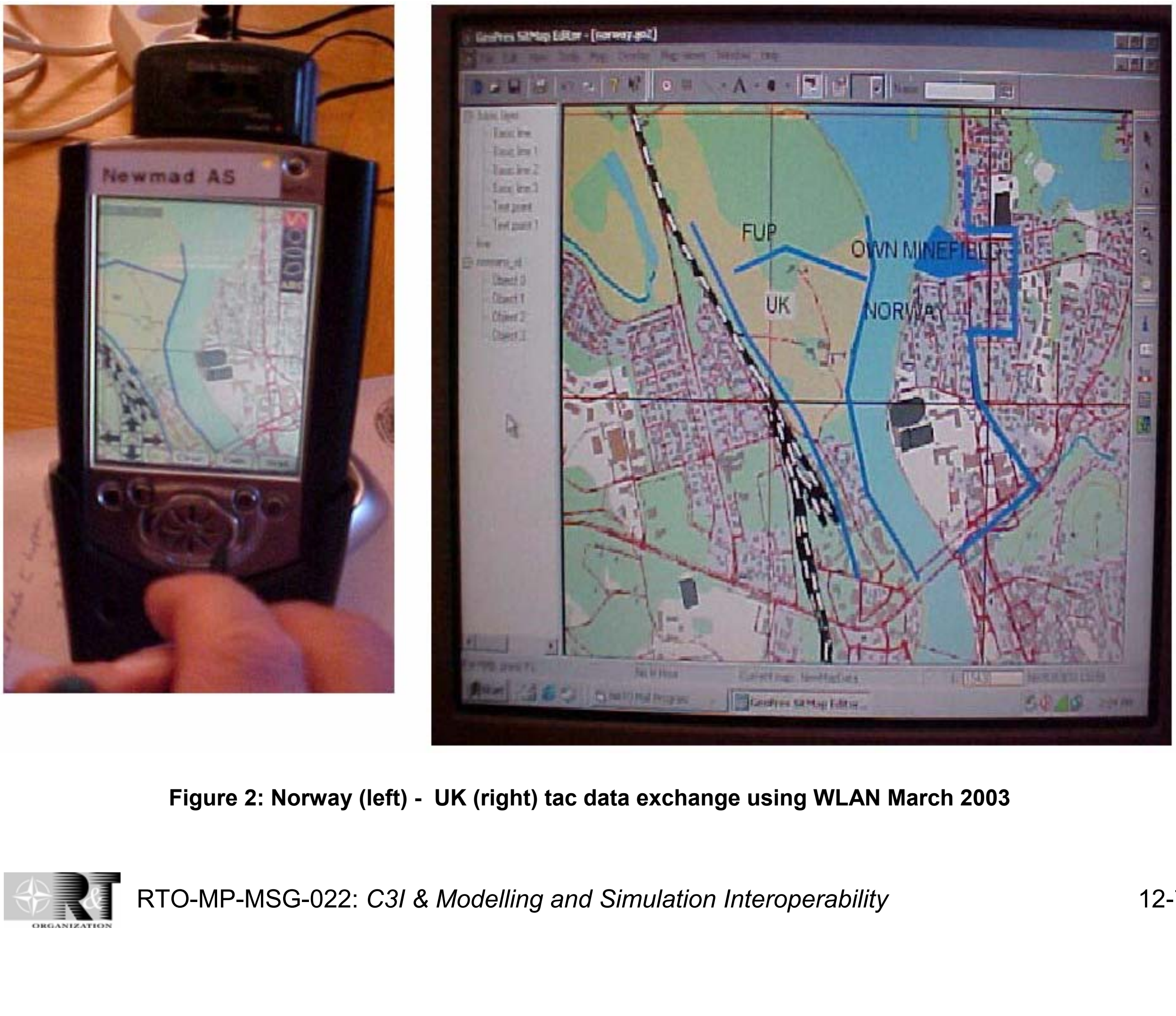

Figure 2: Norway (left) - UK (right) tac data exchange using WLAN March 2003

Alternatively, the exchange could, in theory, be achieved today using a WLAN-based solution, if range/bandwidth performance become adequate.

Security: Here the issues associated with the connection of potentially secure systems have addressed. There are the associated problems of virus control, the potential to 'snoop' on the other system.

Encryption: Encryption can be applied but this will, inevitably, increase the data traffic, with the penalty of added bandwidth being required. Some nations may consider that low-level data that will become 'time expired' quickly and this could be sent with minimal or no encryption over radios with relatively short ranges.

Unauthorised use of systems: TG/1 is addressing issues such as system integrity. This includes problems associated with the unauthorised use of captured radios; an enemy could not gain tactical advantage from knowledge of "blue" positions and intentions but also has the potential to overload networks.

Information conflict: Clearly the potential exists to duplicate information being passed between forces at a higher level. If TG/1's system were implemented, it could be that that information received across the force boundary should not passed up the command chain automatically.

Situating the TG/1 data model within the overall NATO data model: A significant challenge that is being addressed is 'why is another data model needed?' The potential exists to use, for example, the Multinational Interoperability Programme (MIP) data model or, possibly, a derivative thereof, or an alternative NATO data model. The TG/1 / ICOG C4I team is establishing whether any fundamental differences exist between TG/1's proposed model and those that already exist. There is a concern that, as 'soldier carried' systems have limited computing power, driven by the weight/power issue and bandwidth limitations exist with tactical radios, a specifically tailored data model may be necessary. This need must be demonstrated.

STANAG maintenance: Given that computing and operating systems may be frequently updated, consideration has been given to the use of a programming language such as XML as these are operating system independent. XML may be the way to go, provided it does not create an unnecessarily high data-passing requirement. If XML is selected, there is the potential to use the NATO web site for configuration control. A further issue is whether there should be an XML version, tailored to TG/1's needs.

The future

There are 'Strawmen approaches' for the above, but these are in an early stage of definition. If the NAAG, following the demostration of TG/1's experimental work, determines that it is of relevance, follow-on effort would begin to address the aformentioned challenges.

Clearly, the benefit of TG/1's work will, inevitably, depend on national policy. This may be determined bi-laterally, on each coalition operation. It would also require consideration of the level at which tactical information interoperability is achieved; again, this would be a bi-lateral decision, which might be at the platoon commander level.

Any NATO movement towards a greater degree of force mixing, particularly during peacekeeping operations, may also underpin the need for the STANAG. Policy decisions are awaited with interest!

The experimental programme has been genuine international collaboration. as engineers of many nations are working together. There has been a signicant information flow between national programmes meeting one of the other key objectives set by NAAG for Topical Group 1.

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INTEROPERABILITY PERFORMANCE OF CORBA ARCHITECTURE

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Abstract

Multinational coalitions are the standard for land forces in the full spectrum of land war fighting from operations other than war to armed conflict. Recent military events have underlined the necessity of interaction among the peacekeeping participants, most notably through the channels of liaison. Interoperability of the nationals systems, Command and Control (C2) data information exchange, reliability of the systems are chiefly the goals for future National Military Architecture.
The goal of this paper is to describe the opportunity offered to MEADS by the adoption of CORBA (Common Object Request Broker Architecture). The intent is not to describe the current MEADS architecture neither its future planned development; it simply shows, using MEADS as an example, a possible implementation able to underline the advantages that such architecture could provide to a complex Air Defence system.

1. SUMMARY

The paper provides a brief introduction on MEADS system, reviews mainly the general concepts of CORBA Architecture describing the technical details that realize the interoperability in a heterogeneous communication environment, suggesting a possible implementation of CORBA Architecture to an Air Defence System such as MEADS underlining the advantages of the approach adopted.
The last part of the paper describes which kind of analysis has been adopted to estimate the CORBA data load budget that characterize the Architecture of the system taken as an example.

2. MEADS (Medium Extended Air Defence System)

The MEADS System Architecture consists of hardware and software elements configured in a TDMA communications networks that efficiently accomplish real-time Command and Control of total systems operations. Figure 1 shows the MEADS System Concept.
In order to realize Interoperability and Plug and Fight concepts MEADS System will operate in a netted and distributed mode. Netted architectures are seamless and self-healing based on the availability and reliability

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of organic and supporting communications.
Distributed operations are characterized by physical dispersion of engagement functions or groups of functions on the battlefield, wherein data exchanges via broadcast or flood/multi-route patterns may take place over extended distances.
The combination of netted and distributed characteristics reduces the likelihood of a single point failure, which disrupts tactical operations.

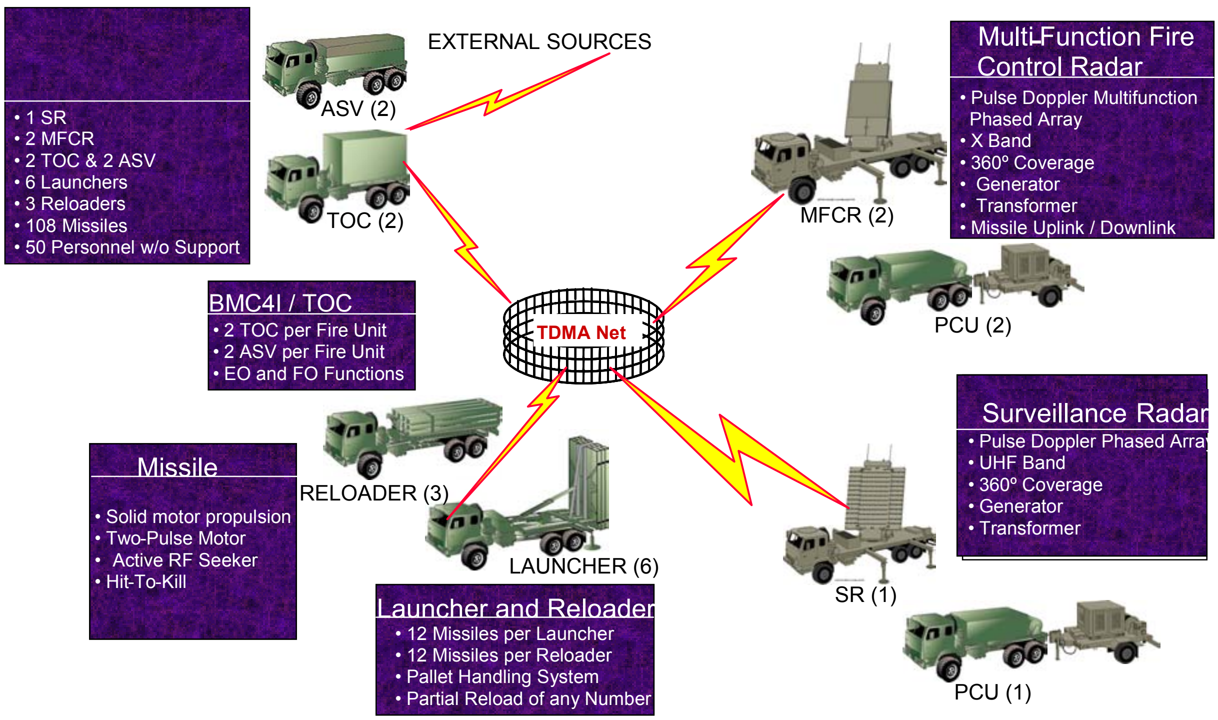

Figure 1: MEADS System Concept

3. CORBA ARCHITECTURE AND INTEROPERABILITY

CORBA (Common Object Request Broker Architecture), OMG's open, vendor-independent architecture and infrastructure, specifies a system which provides interoperability between objects in a heterogeneous, distributed environment and in a way transparent to the programmer.
The central component of CORBA is the *Object Request Broker* (ORB). It encompasses the entire communication infrastructure necessary to identify and locate objects, handle connection management and deliver data. In general, the ORB is not required to be a single component; it is simply defined by its

interfaces. The ORB Core is the most crucial part of the Object Request Broker; it is responsible for communication of application requests.

CORBA applications are composed of objects. An *object* is an identifiable, fully encapsulated entity that provides one or more services that can be requested by a client by means of a well-defined interface (see Figure 2) defined in IDL (Interface Definition Language).

An *interface* is a description of a set of possible operations that a client may request of an object, through that interface. It provides a syntactic description of how a service provided by an object supporting this interface, is accessed via this set of operations. Interfaces and object implementation are totally separated. This allows having multiple implementations of an object, but still a unique interface.

An object *satisfies* an interface if it provides its service through the operations of the interface according to the specification of the operations.

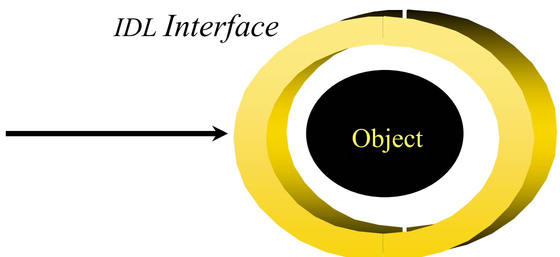

Figure 2: Interface vs Implementation

The basic functionality provided by the ORB consists of passing the requests from clients to the object implementations on which they are invoked. In order to make a request the client can communicate with the ORB Core through the IDL *stub* or through the *Dynamic Invocation Interface* (DII). The stub represents the mapping between the language of implementation of the client and the ORB core. Thus the client can be written in any language as long as the implementation of the ORB supports this mapping. The ORB Core then transfers the request to the object implementation which receives the request as an up-call through either an IDL skeleton, or a dynamic skeleton.

Every object instance has its own unique IOR (Interoperable Object Reference), an identifying electronic token. Clients use the IOR to direct their invocations, addressing to the ORB that manages the remote access to the objects, the exact instance they want to invoke.

When the ORB examines the object reference and discovers that the target object is remote, it routes the invocation out over the network to the remote object's ORB using standards protocols called GIOP (General Inter-ORB Protocol) and IIOP (Internet Inter-ORB Protocol).

Figure 3 depicts the data flow in CORBA

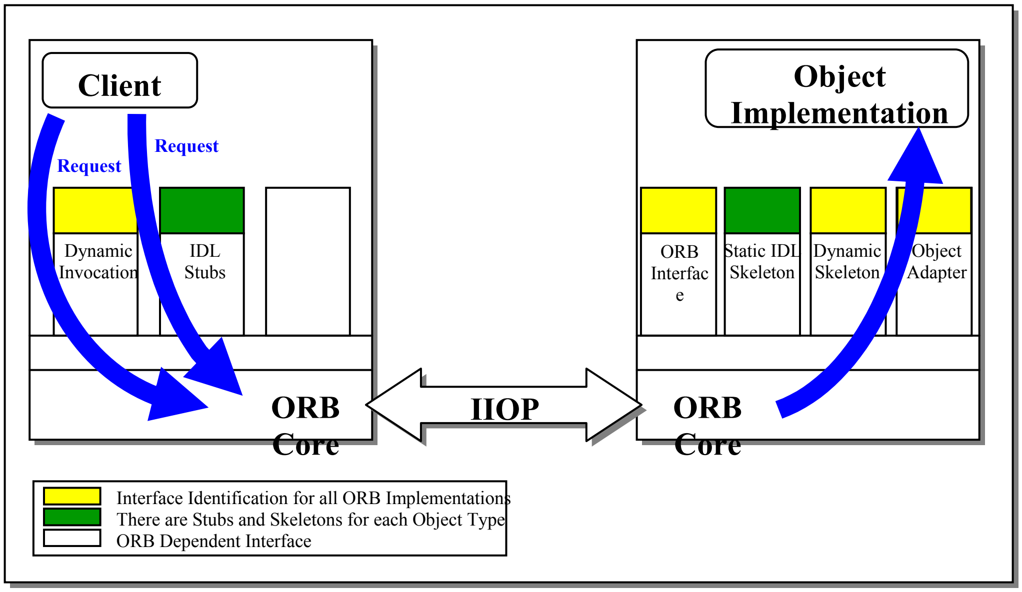

Figure 3: Data flow in CORBA

As depicted in Figure 3, any client that wants to invoke an operation on the object must use this IDL interface to specify the operation it wants to perform, and to marshal (encapsulated) the arguments that it sends. When the invocation reaches the target object, the same interface definition is used to unmarshal the arguments so that the object can perform the requested operation with them. The interface definition is used to marshal the results for their trip back and to unmarshal them when they reach their destination.
Correspondences between ISO-OSI and CORBA Client-Server levels architectures are shown in Figure 4

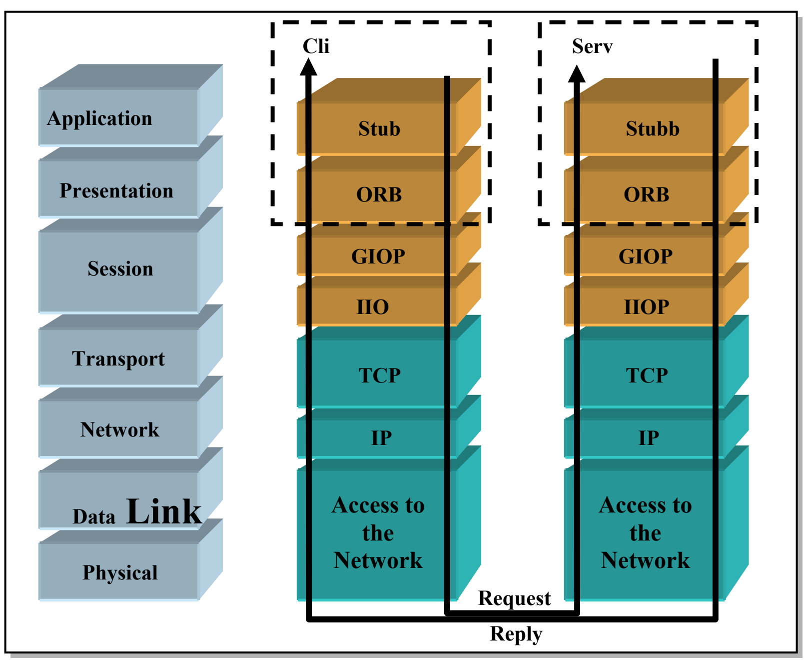

Figure 4: Correspondences between ISO-OSI layers and CORBA Client-Server levels architectures

4. DEVELOPING AN AIR DEFENCE SYSTEM NETWORK WITH APPLICATIONS IN CORBA

Many application domains, such as an Air Defence System, require real-time guarantees from the networks, operating systems, and middleware components to achieve their quality of service (QoS) requirements. In addition to providing end-to-end QoS guarantees and interoperability between each element of the System, applications in these domains have to be flexible and reusable. Requirements for flexibility, reusability and interoperability motivate the use of object-oriented middleware like the Common Object Request Broker Architecture (CORBA).

The core of CORBA architecture is focused on the concept of layered pluggability where various components of the middleware may be "plugged" (included to) or unplugged (removed from) on as-needed basis allowing flexible middleware configuration. End-users call and receive data streams (object's operations request and results) from different sources without the need to know the exact location of the sources or to have specialized processors to capture the multimedia data.

For MEADS, as it is depicted in Figure 5, in order to implement the CORBA architecture in a distributed and netted network the objects are covered by the elements of the System MEI (Major End Items), Sensors, Launchers and TOC and the object's applications are represented by their functionality ("target tracks", "target identification", etc.).

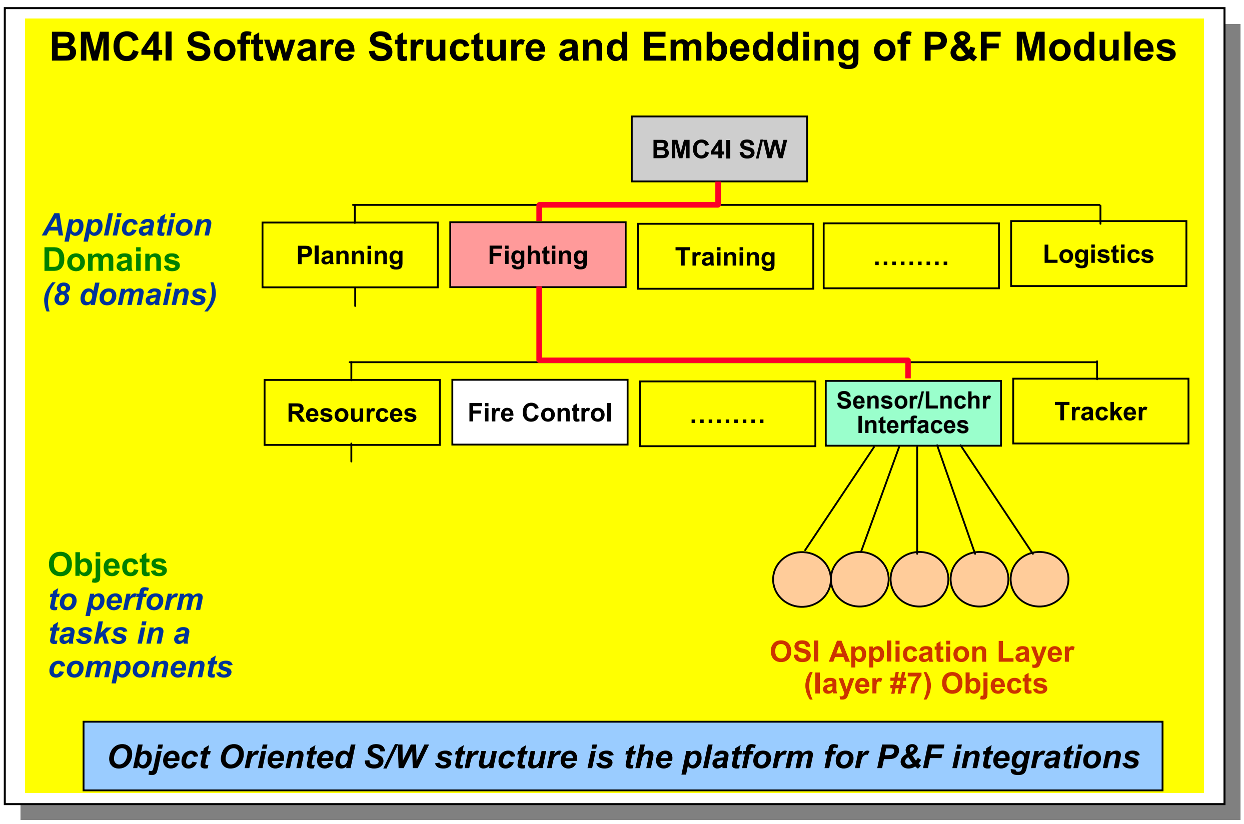

Figure 5: BMC4I Software structure

The configuration network proposed is an hybrid configuration: each element is ready to share its applications but always passing through the TOC that represents a client for a fire unit, but could also be seen as a server in a Battery or in a wider Integrated Defence System.
A client (TOC) can invoke an operation to the server object by sending it a Request message. This type of message contains all the information that is required to make a remote method invocation. A server object (sensors, launchers) responds to a client's invocation containing the response to the Request. Figure 6 shows the hybrid configuration concept described above.
Adopting the same architecture other "objects" may be in easy way "plugged" to the system realizing successfully the concept of the scalability, evolvability, and interoperability.

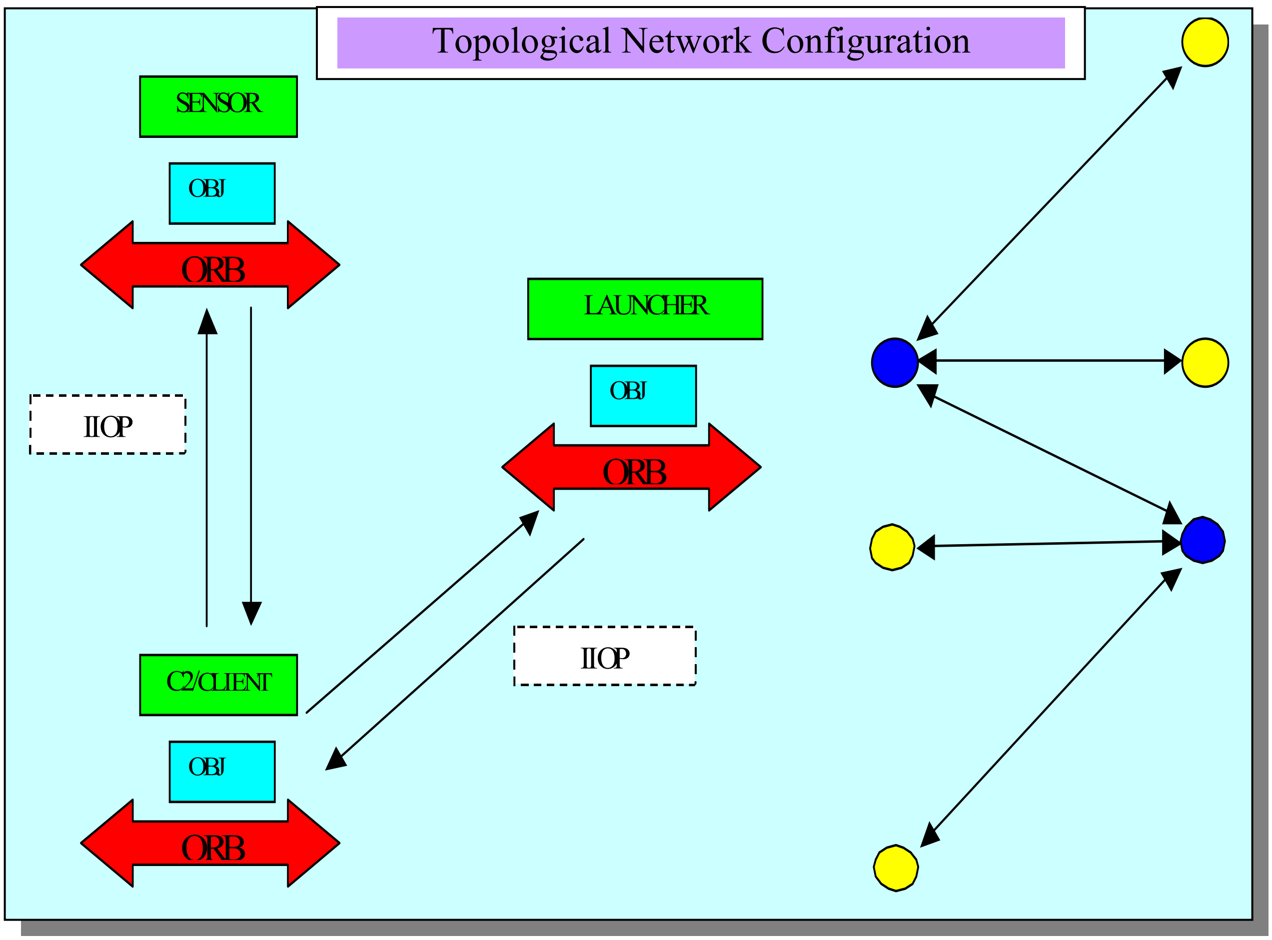

Figure 6: Hybrid configuration network

In Corba Architecture, every object instance has its own unique Interoperable Object Reference (IOR), well-identified and unique electronic token. The clients, the TOC or other C2 units, use the IOR to direct their

invocations, identifying to the ORB (Object Request Broker) that manages the remote access to the objects, the exact instance they want to invoke. When the ORB examines the object reference and discovers that the target object is remote, it routes the invocation out over the network to the remote object's ORB using GIOP and IIOP. Figure 3 depicts the data flow in CORBA.
GIOP is a protocol that defines an ensemble of messages available between client and server underlining the communication syntax between different ORBs.
GIOP use a standard binary format for the transmission of the IDL type messages, called Common Data Representation (CDR) that define the order and the alignment of the Bytes for each IDL message.
The characteristic of the CDR coding permit a good efficiency in the marshalling technique but the length of the messages is not optimum.
The receiver node sees the messages as a stream of not formatted bit.
In GIOP protocols are defined eight types of messages whose only two are really important for the flow of the messages between client and server:

- *Request*: the client sends this kind of message to the server in order to invoke one particular operation.
- *Reply*: the server sends this kind of message to the client in order to satisfy the invocation.

The duty of the IIOP protocol is to link GIOP protocol with TCP/IP (mapping), defining all the information regarding the address of the objects.
These informations are included in the IOR of the object, so the IIOP has only to specify in which mode the IOR address this kind of information.
Figure 7 shows the general structure of the CORBA Message.

IP Header 19 byte	TCP Header 19 byte	GIOP Message Header 12-byte	Variable-length GIOP Message Body

Figure 7: Structure of a CORBA message

5. SIMULATION DATA TOOL

The data load budget of the netted and distributed Air Defence System architecture under study, has been analysed using a NAMEADSMA customized simulation Tool, characterized in input by the Action History output file of EADSIM (Extended Air Defence SIMulation) that runs on a predefined and user-selectable scenario and the set of CORBA Messages. The type of scenarios used vary from Mass Attack (Many-on-Many) to a One-on-One configuration.
The Tool implements a mapping between EADSIM messages taken from the EADSIM output Action History file and the CORBA messages, taken into account the estimated timeline of the System.
Figure 8 shows the Network data load Simulation tool functionalities and how the various entities involved are interfaced each other.

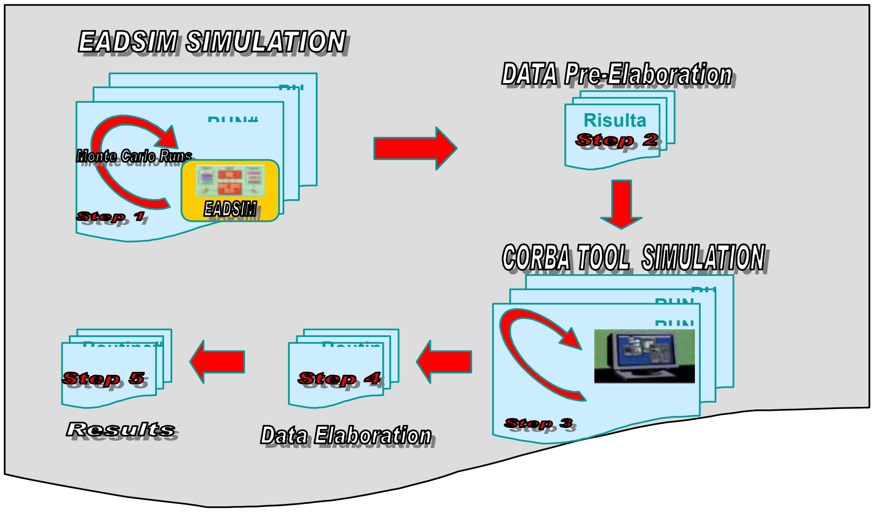

Figure 8: Network Data load Simulation tool

This simulation tool allows the operator to select, through a user-friendly interface, the data bit-rate, the Sensor tracking frequency and in a future version it will also incorporate the possibility to compare directly a TDMA implementation with the features of a CDMA one.
Figure 9 and 10 show the result of the simulation data tool: as a result of running the simulation tool the network data load of the system under analysis is shown in figure 9 detailing the load of the single MEI while chart in figure 10 details the load of the whole system in percentage as a function of time.

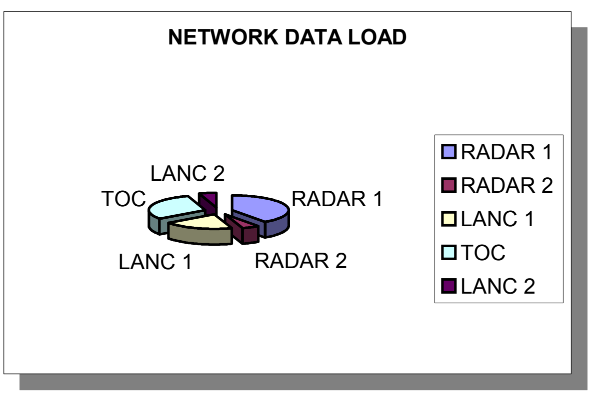

Figure 9: Network Data load

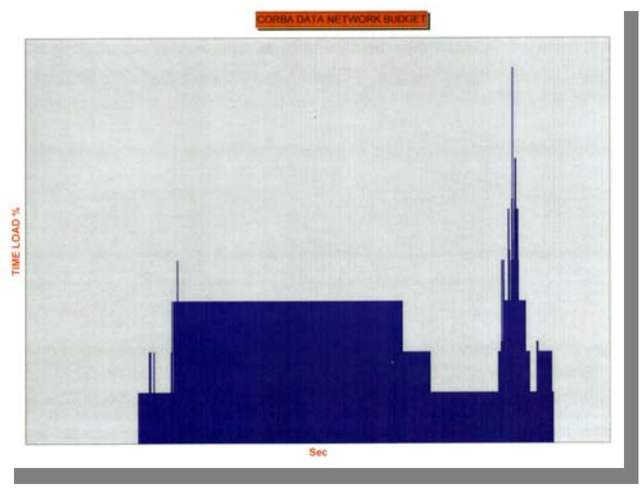

Figure 10: % Time load as a function of time (sec)

One of the possible applications of this Simulation tool is to analyse and establish the interoperability degree between two different Air Defence systems, between single components (MEI) of different Weapons Systems characterizing them as distributed application shared on the same CORBA network.

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Generic Representation of Military Organisation and Military Behaviour: UML and Bayesian Networks

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ABSTRACT

To be able to model systems for C2 we have to evaluate and find appropriate methodology for modelling and representation of our knowledge about military organisations and military behaviour. Military organisation and military behaviour are important parts of C2.

In this paper we present a study of modelling military organisation and military behaviour in a generic manner, using two different knowledge representation techniques: the Unified Modeling Language (UML) and Bayesian Networks. The class diagram that is provided by UML is well suited for representing military organisations whose structure is well-known, since military units and their interrelations can be represented as classes and interrelations between the classes. On the other hand, it is a much harder task to represent military organisations that are not well-known or military behaviour because of the uncertainty associated with them. Different behaviours are triggered in different environments using different doctrines, and the outcomes of the behaviours are uncertain. Due to complexity, time constraints and war friction, causal relations between different factors, which play an important role in warfare, may be uncertain.

Bayesian Networks seems to be a reasonable choice for representing uncertain military behaviour as well as uncertain military organizations, since this method combines uncertainty and a priori knowledge in a homogeneous way. We can compare those models and facilitate the verifying process. As result we get a more reliable BN and the modelling time decreases.

1.0 INTRODUCTION

Our intention with this paper is to highlight the need of interaction between two different modelling techniques, Unified Modelling Language (UML) and Bayesian Networks (BN). Despite the fact that these techniques are very different and are used for different purposes, we propose an approach generic UML modelling of military organisation and military behaviour as a first step towards modelling with BN. Modelling with BN involves nets with high complexity and a structured overview is required. UML class diagrams enable a good visual overview of class structure and relations between different classes. Having a UML structure in the "background" makes it easier for us to implement large BN networks. Finally we can compare those models and facilitate the verification process. As result we get more reliable BN models and modelling time decreases.

Military organisation and behaviour are described in military doctrines. The first issue is how to model doctrines on a conceptual level and the second issue is how to implement these concepts in a concrete model. The connection between the conceptual level and a concrete model is also discussed in this paper. Modelling on the conceptual level has been performed by using textual and graphical documentation techniques associated with the Unified Modelling Language (UML) and Bayesian Networks (BN), respectively. Implementation of the model was performed in MATLAB. The implementation is a BN model which uses some of the classes and variables represented by a UML model.

In this paper we will represent a doctrine class diagram in UML with focus on ground forces, as well in a BN model, and finally discuss UML and BN as modelling techniques. The BN model that we have implemented represents a relatively small part of the UML doctrine model. The UML model can be used for more general purposes while the BN model is used to model the behaviour of a relatively small hostile force unit that acts in a certain environment.

The importance of developing generic models in command and control (C2) is increasing due to issues of co-ordination, co-operation, training, decision support etc. When modelling warfare a plethora of factors has to be considered. In such complex problems the increasing need for classification of knowledge arises. We found it important to perform such a classification in a generic manner. The class models could then be reused with some modification and should be easy to update. Consequently, the modeling expert can concentrate on one part of the model at time. E. g., one generic model of a military organisation and military behaviour can be reused for modelling different doctrines and for different purposes by using a well-known modelling technique. Consequently, we have performed a UML classification of doctrines in a generic manner. BN are able to represent uncertainty that arises when modelling doctrines, e. g. fog of war, especially when modelling enemy organisation and military behaviour.

2.0 MODELLING TECHNIQUES

2.1 Unified Modelling Language

In this work, we use two different modelling techniques. The first one is the Unified Modelling Language (UML, see [1]). UML is a set of graphical description techniques for specifying, visualising, implementing and documenting object-oriented systems [2]. The aspect of the Unified Modelling Language (UML) that has been used in this paper is the class diagram. We have not performed sequence diagram representation in UML because of the tremendous complexity of the military operations considered here.

The class diagram in UML provides graphical representation of object types, also called classes. The model describes relations between classes in a uniform way by using a standardised representation. A class is a template containing mutual properties of a group of objects. Types of the objects, classes, may be everything from physical objects, e.g. tank, to abstract objects such as plan and task. A more general definition of the class concept is that the class is a set of objects with the same behaviour which are of the same type. "*Object-oriented methods also provide means to increase reuse of design efforts, including the concepts of patterns and the generalization/inheritance relation. These means offer the possibility to describe problems and to model properties of objects in a generic fashion, considering only common features before instantiation for the specific case*" [3].

When we want to describe a class model in UML we first identify interesting classes and after performing that step we describe relations between them. Consequently, we make a generic structure that can be used for implementation for different purposes.

The first step towards a UML modeling was to collect knowledge about military organisation and military behaviour. Most of this knowledge has been collected from doctrine manuals. In our model we use a representation of Swedish doctrines, although in generic manner. By using this kind of modelling approach, the UML structure can be reused/generalised to model other regular military organisations with some modifications.

Doctrines provide hints about how military tasks should be carried out. This means that some of the military behaviours can be classified. Given information about environment, force balance, opponent's position and other rules that have influence on military behaviour we can say that some behaviours are more probable to occur in some situations. UML has a very good expressive power for classification. Class diagrams in UML give very good overview but we cannot say anything about the probability that a given class, in this case a class describing a particular behaviour, will occur. E. g. we found it difficult to express how using UML a class representing frontal attack behaviour of some hostile military unit is likely to occur given the information that we are close to the enemy and the fact that visibility is good. In some cases certain classes are irrelevant and in other cases they are important.

Relations between attributes of different classes cannot be represented in UML class diagrams. Instead, in a UML class diagram we specify relations between different classes.
On the other hand, the advantage is that the principle of encapsulation makes it possible to build implementations that have parts which are more autonomous, objects in UML.
In BN instead of attributes we have variables. We see the attribute as a generalisation class of class variable in UML.

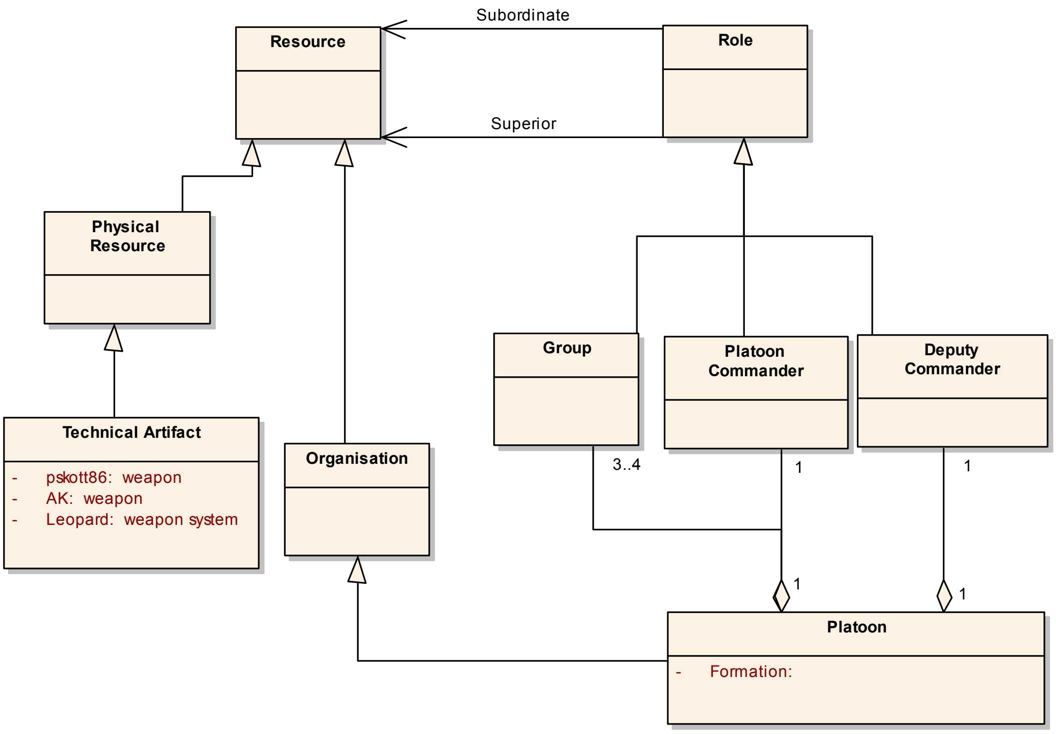

Figure 1: UML model of a platoon

The model in Figure 1 is developed and improved from an even more generic model of C2, see [3]. The interpretation of the figure above is that one *Platoon* consists of three or four *Groups*, one *Platoon Commander* and one *Deputy Commander*. The *Platoon* has an attribute *Formation* with four possible values: Lead, Battle Line, Stepped Formation and Battle Triangle. This variable, attribute in UML, will be represented in BN with these values. *Platoon* is an *Organisation*. The subset of *Physical Resource* class is a class of *Technical Artefact* which contains attributes that correspond to the technical equipment of the platoon in this case. As we see in this class diagram we do not have any description of relations between attributes.

When modelling a hostile military organisation we do not always have complete information about it. E. g. we may not know how many tanks an enemy tank platoon consists of. Let us say that in other cases hostile platoon consists of three or four tanks, in some cases there are also some other vehicles in a platoon. In UML we can express this relation as "the platoon consists of three to four groups". A statistical interpretation of that statement may be the uniform distribution over the number of groups. That implies that the hypotheses three and four groups are equally probable. There is no convenient way in UML to express for example our knowledge that four groups is more frequent than three groups. A deficiency of the UML is its inability to represent uncertainty in a comprehensive way.

2.2 UML doctrine model

In Figure 1 we showed the model of a platoon. In the same manner Figure 2 shows a company model. This model also represents the relation between company class and platoon class hence obtaining a hierarchical representation.

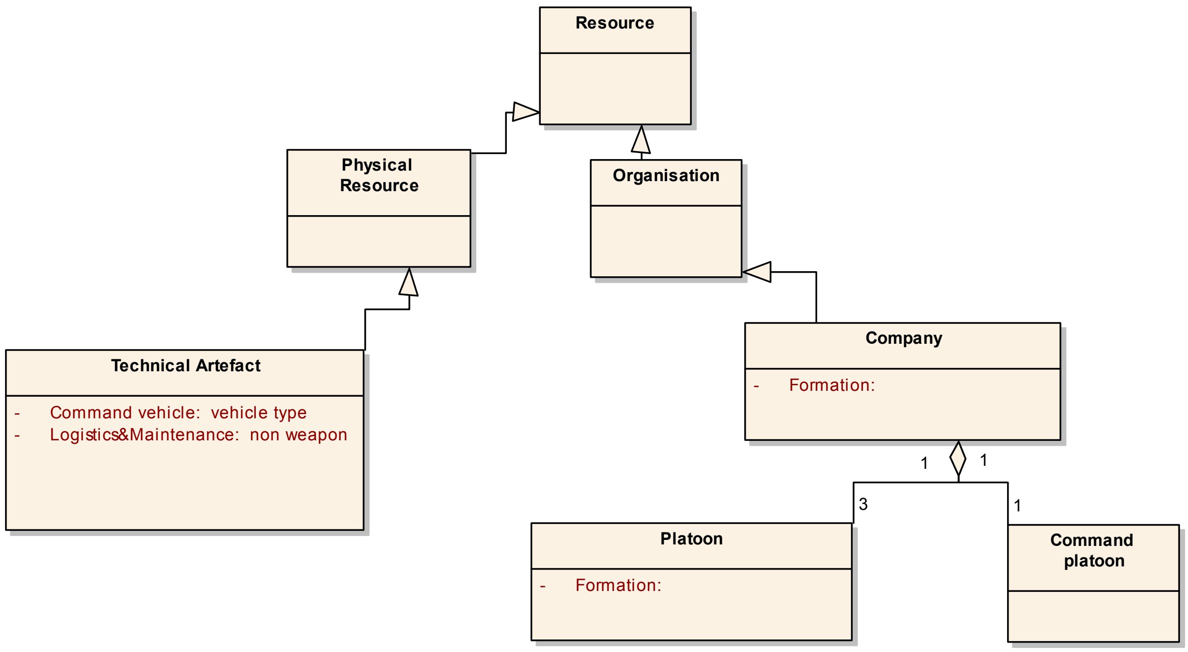

Figure 2: Company description with UML

It is not enough when modelling military doctrines to describe relations between different units, their roles, which resources are they part of, and which resources are put to their disposal. Military behaviour is however an important part of doctrines that is not part of the model. In concrete situations there is a list of the military behaviours/actions to be executed. In Figure 3 we show a model in which relations between military behaviour as a part of planning, military organisation and environment are represented.

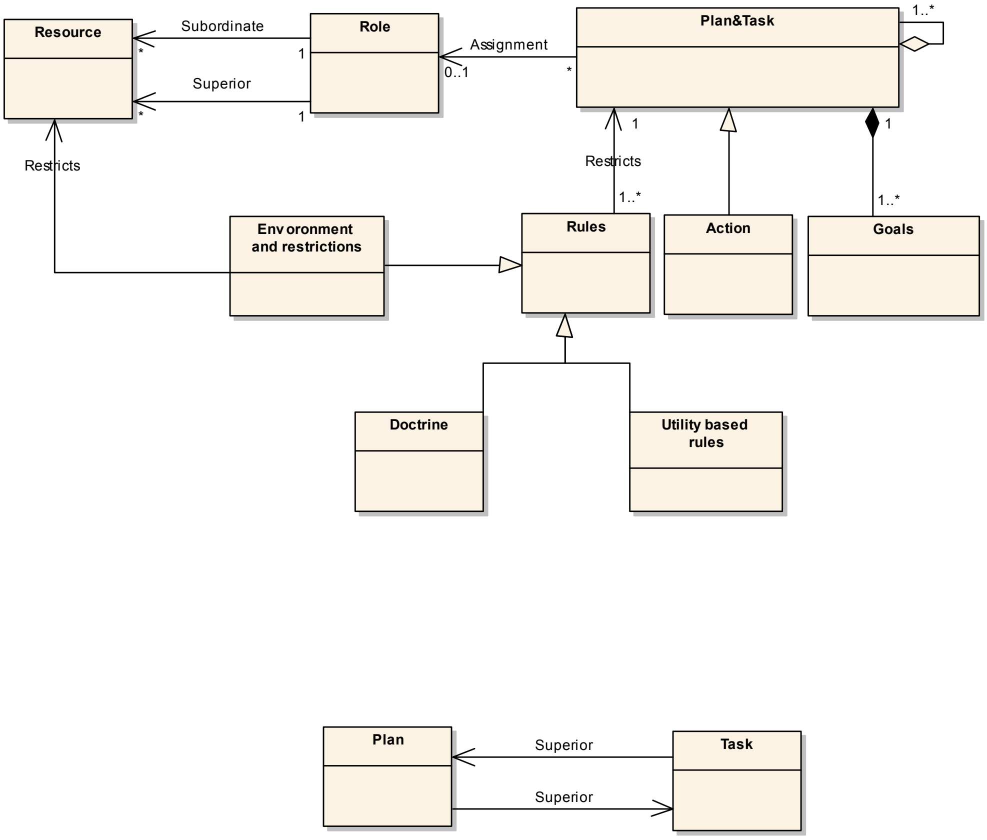

Figure 3: Planning, doctrine and environment

We recognise this kind of problem in AI as the agent planning problem under uncertainty; see [4]. As we see in Figure 3, environment rules and doctrine rules are subsets of more general rules in an agent planning problem. Utility-based rules represent all rules that are not described in manuals but are frequently used. Some military or paramilitary organisations, for instance, lack doctrine rules. Plan and task are assigned to the role which can be for example a commander of a military unit or tank driver. In order to solve the task and execute the plan a role has to use resources. The role can be part of a larger plan and be subordinated to a resource, e.g. platoon member is subordinate to platoon.

Part of the model is also the environment, which plays an important role when making plans. It is regarded by military commanders both as opportunity and as restriction to execution of their plans. Information about the opponent is also important when making own plans. However representation of some “generic” opponent is not performed in our UML diagrams, although it was modelled with our BN model of a particular hostile tank company.

2.3 Bayesian Networks

In general when modelling warfare we have to deal with uncertainties. Prediction, fusion of the uncertain information, war friction, enemy courses of action etc., are examples of where a high degree of uncertainty is involved.

Bayesian Networks is a statistical modelling method used to represent uncertain causal relations between different statistical variables.

The graphical representation of BN, is different from that of UML and uses nodes and arcs representation. Only one kind of relation between variables is described. This kind of relation is also called “influence relation” hence BN is also subset of influence diagrams.

Each node represents a variable that can be either discrete or continuous. Variables and its states are represented by conditional probability distributions also called subjective probabilities. BN is also denoted *belief network* since they describe our belief about the state of the variables.

When new evidence arrives, the probability density function over each variable’s states change and new belief propagates through the network weighted by our subjective probabilities. An advantage of the BN is that our knowledge is implemented in a fragmented manner. We only have to “explain” how a particular node depends on its parents. E. g. in Figure 4 we define the probability density function of the variable *WetGrass*. The variables that make direct influence on the variable are called parents. *WetGrass* in this example has parents *Sprinkler* and *Rain*. The a priori probability density function of variable *WetGrass* does not model influence of the variable *Cloudy*. However, let us say that new evidence arrives. The statement of the new evidence is that we know that the weather is cloudy, *Cloudy* = True, this evidence will propagate through the network and make influence on our belief about if grass is wet or not. The process where weighing the new evidence with our subjective, a priori, knowledge is performed is denoted statistical inference.

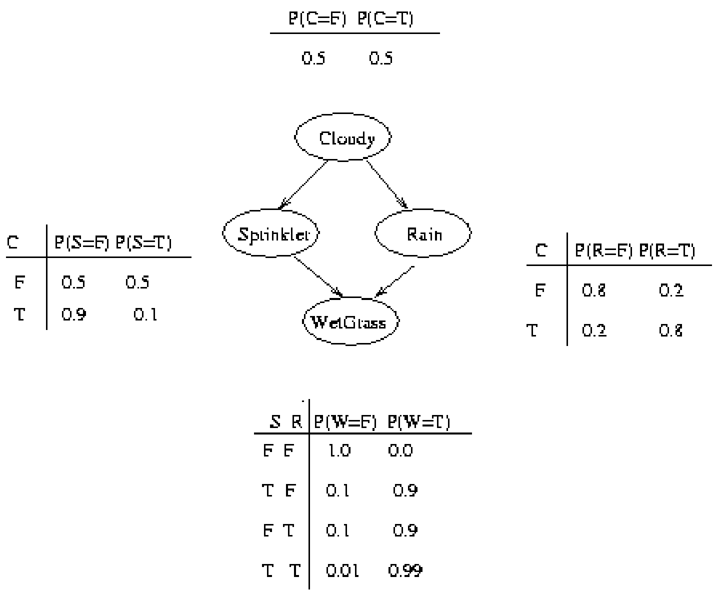

Figure 4: An Example BN [5]

When using BN we can infer evidence in all directions by using the Bayes rule. E. g. we can answer the question what is the probability that the sprinkler was on if we perceive that the grass is wet. The causal relations give only a description of the model.

According to [6] the formal definition of BN is:

- A set of variables and set of directed edges
- Each variable has a finite set of mutually exclusive states
- The variables together with the directed edges form directed acyclic graph (DAG)
- To each variable A with parents B1 .. Bn there is attached conditional probability table P(A| B1 .. Bn)

Mathematically expressed:

$$P(X_1..X_n) = \prod_{i=1}^{n} P(X_i \mid par(X_i))$$

Where ***n*** is the number of the nodes in the network and $\boldsymbol{X_i}$ represents a stochastic variable no. ***i*** of the BN.

When we describe a time-dependent BN we speak about Dynamic Bayesian Networks (DBN). It consists of several layers of BN with the same structure. The additional influences in DBN are the variables of the previous step(s) that make influence in variables for future step(s). Note that the term "dynamic" means that we are modelling a dynamic system, not that the network changes over time [7]. The variable values changes over time but the network topology remains same.

The problem of how to handle complexity arises when we want to describe behaviour of many military units instead of one military unit. The BN becomes very large with many state variables. When we model a clear conception of how the system works is required. As the number of variables grows, the difficulty of envisioning such a model increases enormously [8]. Therefore the process of classification and describing relations between classes is required.

The important issue is how to build a BN from the UML class diagram. As a first step we create a BN representing a military unit, a platoon in this case. The hostile platoon's behaviour depends on factors like environment, platoon doctrines and superior unit behaviour, a hostile company in this case. When we implement the BN we realised that we cannot use the principle of reuse/generalisation more than copy and paste of the BN fragments. In this particular example we realised that we had to copy the BN representing platoon three times. The drawback of this BN is, beside the fact that we had to manually rename variables for platoon two and three, that when we wanted to change a structure of the platoon representation we had to change each platoon fragment. The structure of the UML military unit and planning model facilitated the work of modelling (D)BN representing a hostile company but no formalism has yet been applied.

2.4 A Hostile Company Bayesian Network Model Example

In this section we describe a particular BN model that is used for recognition of enemy plans. On-line multi-agent stochastic policy recognition aims to detect which policies an agent or group of agents are executing by observing the agents' actions and by using *a priori* knowledge about the agents in a noisy environment. The method chosen for the representation of this task is Bayesian inference using dynamic Bayesian nets. The inference is intended to derive belief measures for enemy plans.

In military applications the issue is how to recognise certain military behaviours of the enemy. Using the movement pattern, speed, distance, visibility, maneuverability distance to presumptive target etc., it might be possible to fuse the acquired knowledge about the enemy and use it in policy recognition. The advantage would be that military commanders, having better knowledge about the enemy's intentions, will be able to act earlier. The ability to act preventively increases as well.

The purpose of the network is to make qualified estimation of the opponent's behaviour based on observations, knowledge about opponent's doctrines as well as data from the terrain.

As the first step in making a company BN, we make a BN of a single hostile platoon. We specify variables in the graphical diagram. After that, the causal relationships between variables are specified. Finally, we define conditional probabilities to "explain" how a certain variable's values depends on its parents values. E. g. we previously mentioned variable Formation, see section 2. 1, that may have following values: Lead, Battle line, Stepped Formation and Battle Triangle. We define a conditional probability distribution over all possible combinations of values. In Figure 5 we see the node representing the variable formation.

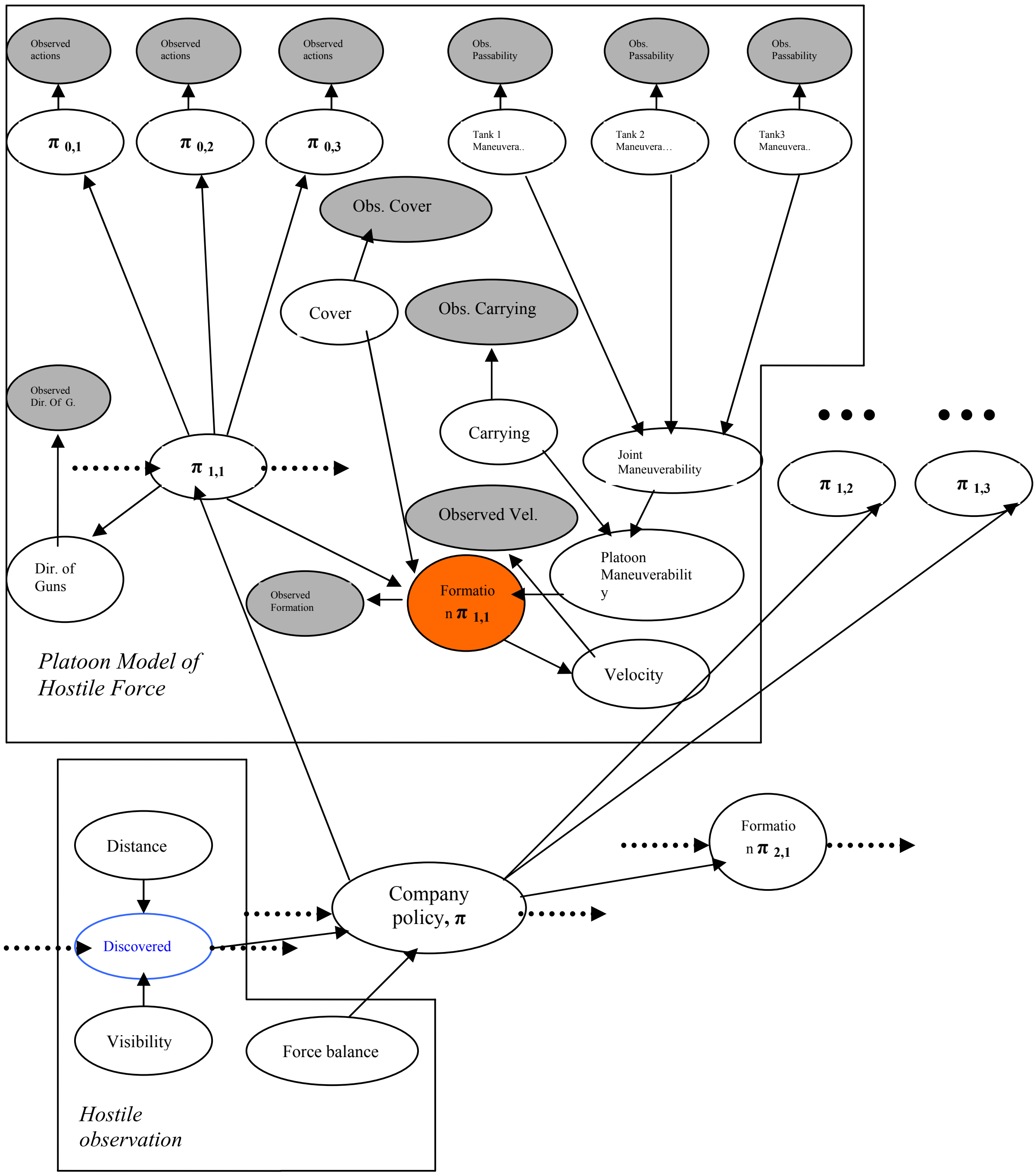

Figure 5: Planning, doctrine and environment

Formation has following parents: platoon manoeuvrability, platoon policy and cover. By defining our probability distributions we model our a priori knowledge. E. g. the formation battle line is less probable to be used by the hostile formation when the manoeuvrability is bad. The formation battle triangle is more probable to occur in this case if the variable of platoon policy is attack. The variables formation, distance to presumptive target, and direction of guns are used to connect observations to different policies. We denote these nodes doctrinal nodes.

After building a platoon model we define a company model that consists of three platoons. In this case we intended to define a platoon class with three instances. But modelling with classical BN does not support this kind of approach. Instead we had to perform a cut and paste process and when we wanted to change the model of a platoon we had to change it in all the three instances.

The second drawback of the BN was that connection between platoon and company model is only via variables. The principle of encapsulation does not exist in classical BN. One of the problems is that fragmentation of the BN could violate laws of the statistical inference.

The hostile company BN model was implemented in MATLAB. It takes environment, doctrines and new information about enemy forces movement into account. We are able by using this model to observe the most probable policies that the enemy is executing on different abstraction levels.

3.0 DISCUSSION AND CONCLUSIONS

The UML and BN are two different modelling methods for different purposes and for different modelling approaches. Nevertheless we propose a modelling approach that combines knowledge incorporated in UML-class diagrams when modelling BN. The reason is that when using a generic well defined structure the process of modelling large and complex BN is facilitated.

In order to facilitate future modelling process, the concept of Object-Oriented Bayesian Networks (OOBN) should be studied. Especially this concept could be useful when modelling large military formations with (OO)BN. This principle of modular and reusable representation of a BN, OOBN, has been applied in a probabilistic representation language (SPOOK); see [8].

Some parts of programming code of OO-languages as Java and C++ can be generated directly from UML. Is it possible to develop a formalism that generates at least some parts of a BN from UML in similar manner? There are many obstacles to achieve that. One of them is the difficulty of UML to handle uncertainty in a uniform way. A uniform notation to express uncertainty in an easy and comprehensive manner should be developed for UML.

Also the inconsequent fragmentation of BN in classes could violate rules of statistical inference. However, we are convinced that a new kind of approach of designing BN is required to achieve better compatibility with OO-methods.

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The Modelling and Simulation of A Messaging System of a Model Brigade

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ABSTRACT

The need of information on tactical battlefield will increase in future battles. Not only to gain information on battlefield, but also to convey it where it is needed on time, will be very important. The next generation mobile tactical communications systems will provide a robust, reliable, secure and flexible network to the mobile users of tactical battlefield. However, it is a question under interest to predict the impacts of different battle conditions on their performance. We conducted a simulation study of a messaging system of a model brigade which mobile users use TDMA (Time Division Multiple Access) radios and TDMA technique for channel access. We identify a set of components, which are called Mobile Subscriber Terminals, Personal Subscriber Terminals and Radio Access Points that make up mobile wireless network. The mobile wireless network can provide networking facilities and many simultaneous voice and data connections to the mobile users. The focus of this study is to construct a simulation model of a messaging system of a model brigade on tactical battlefield and to determine if the system is capable of supporting the data exchange in performance criteria under different conditions. The simulation is performed by using Arena 7.0 simulation program and results are analysed by using SPSS statistical package program.
Keywords: *Simulation, messaging system, mobile wireless network*

1. INTRODUCTION

The success of military operations on today's tactical battlefield is closely related to the C4I (Command, Control, Communications, Computer and Intelligence) concept. Gathering, exploiting, and protecting information is critical from the view of C4I concept. To achieve the C4I functions the existence of a secure, robust, reliable and mobile communications infrastructure is very important. This infrastructure should be capable of conveying messages, data, imagery, and video files as well as voice communications among the fixed and mobile components of the battle forces in a secure, and timely manner.

Advances in technology affect the way that the warfare is conducted. Recent improvements in information, computers and communications technology such as broadband networks, digital cellular systems, wireless computer networks, evolving computer systems, global positioning and other technologies opened new horizons in the communications systems. Electronic mail, cellular telephone for voice and data, vehicle position reporting/tracking systems, and many other products have appeared. With these evolving technologies, today, the efforts to reach the goal of "digitizing the battlefield" increased. The intelligence about the battlefield such as the strength and placement of the enemy, the geographical positions of friendly troops are tracked and analyzed with computers and, again these computers can be used to pass the information between components of the battlefield. These improvements provide future

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war fighters and decision makers with accurate information in a timely manner.

In our study, we develop a simulation model of the messaging system of a model brigade on the battlefield. In the messaging system, information in forms of messages, reports and plans are accomplished with personal computers. GPS information is automatically updated, giving subordinate units complete knowledge of the friendly situation; thus a common view of the battlefield. The multimedia (video, imagery) is one of the most important parts of this information. The users of the system are mobile and use Time Division Multiple Access (TDMA) radios to send this data. We examine the behavior of the messaging system to determine if it is capable of supporting the needs of the users in the battlefield. We also investigate the significant factors that affect the system performance and their relationships. Finally, we evaluate the system under different types of operations. The objectives of this study are to;

- develop a simulation model of a brigade messaging system,
- examine the behavior of the communication system to determine if it is capable of supporting the messaging needs under different conditions for various performance measures,
- analyze the effects of the model parameters on the performance,
- establish the nature of the relationships among input factors and system responses,
- compare system responses under different circumstances.

The outline of the paper is as follows: In Section 2, the system is briefly described. In Section 3, the simulation model is explained in details and validation and verification of the model is discussed. The results of the output analysis and experimental design are presented in Section 4. Finally concluding remarks are given in Section 5.

2. THE SYSTEM DESCRIPTION

In the brigade structure that we model, there are a Brigade Headquarters, a Communications Company, an Antitank Company, an Engineer Company, an Air Defense Battery, an Artillery Battalion, two Mechanized Infantry Battalions, and two Armor Battalions. All units in the brigade messaging system use mobile subscriber terminals (MST) or personal subscriber terminal (PST). A MST is a terminal, which is used for both voice and data communications. It is generally mounted on a vehicle. Also, it may be connected to a computer to send data, multimedia or imagery. MSTs transmission range is maximum 10 km in the line of sight (LOS). A PST is a terminal, which has the same features with MST except output power, transmission range and dimensions. Its transmission range is maximum 2 km in the line of sight. A Radio Access Point (RAP) is the gateway from LAS network to the WAS backbone. Units reach the subscribers of other networks via RAP. Units use TDMA scheme to access the channel. Units using the same frequency band can communicate with units that are in theirs transmission ranges and can form a radio network automatically in the tactical field. Also, units can act as a relay to the voice or data connections of other units without interrupting communication services to its own user. For voice calls and data connections, a maximum of 3 and 5 hops are available respectively, while real-time video transmission is only available for the destinations in the transmission range. Units contain internal GPS receivers and obtain position location information from the GPS system. The GPS information is automatically distributed in the network.

There are many types of data including voice over radio, orders, operations plans, reports, maps, real-time video files, etc. that the users will exchange in the system. However, we classify these data into four groups as voice calls, messages, real-time video, and other data files. The transmission speeds to send these data are 4.8 Kbps, 9.6 Kbps, 64 Kbps, and 9.6 Kbps and the needed number of channels to realize the transmission are 2, 4, 24, and 4 respectively.

We use a distributed asynchronous version of Bellman-Ford algorithm, which is in the class of table-driven routing protocols in our study. In this protocol, each user holds a routing table containing the length of the shortest path to the every destination in the network. An update packet is broadcasted by a node when a topological change is detected. This packet consists of only changing nodes. Every node updates its routing table according to this information. When an update packet is received from a neighbor node, an acknowledgement of the update packet is sent to the neighbor node. This process will be repeated until all the nodes have updated their routing tables. Also, each node broadcasts its routing table periodically. The update data is kept for a while to wait for the arrival of the best route.

We use distributed time slot assignment protocol (DTSAP) [1,2] for channel access. DTSAP is in the class of conflict-free, dynamic allocation, reservation based, multiple access protocols. In this protocol, every unit has its own control channel, which is designated by RAP. In control channel the unit broadcasts its position information and call related information to the network. A frame consists of 28 data channels. Using DTSAP, transmission of data or making a voice call occurs in a two-stage procedure. In the first stage, a connection between source and destination node is established and in the second stage data is transmitted through the route or voice call is made. When a node wants to make a connection with destination node, it first sends a connection request packet to the destination node if it is in transmission range, or to the next hop in the route to the destination if it can be reachable in allowed number of hops. This call request packet involves the address of the destination node, number of the channel needed and the data channels that the node cannot broadcast and receive. Upon receipt of connection request packet, the relay unit selects the channels for transmission under following constraints:

- The source node and relay unit cannot broadcast or receive from the data channels dedicated for other transmissions.
- The source node cannot broadcast from the data channels that its neighbors receive and the neighbors of relay unit broadcast.
- The source node cannot receive from the data channels that its neighbors broadcast.
- The relay unit cannot broadcast from the data channels that its neighbors receive and the neighbors of the source node broadcast.
- The relay unit cannot receive from the data channels that its neighbors broadcast.

If the channels are available, it sends a connection confirmation packet that includes the selected data channels. Otherwise, the connection request is rejected. If the relay unit is not the destination, it starts the next leg of the connection towards the destination node. After a connection is established, the destination node sends a call-accepted packet back to the source using data channels. After the call accepted packet is received, the source node starts transmission of data. The communications between source and destination node is full duplex which means the source and destination node can send data to each other simultaneously. At the end of every packet the destination node, if it has successfully received the packet, will return an ACK (acknowledgement) packet to the source node. The source node will retransmit the packet if it had not received an ACK packet after a defined period. When a node detects a new neighbor during transmission, it sends a resolve conflict packet, its time slot assignment table and its routing table to the new neighbor. The neighbor terminates all connections that have a conflict and it broadcasts its revised routing and time slot assignment tables in its control channel. All nodes update their routing tables according to new topology. After all data transmitted or if a node determines that it has no longer connected to a node in the route, to terminate the connection, source node sends a clear request packet in the data channel. Upon receipt of clear request, the destination node and the nodes on the route sends a clear confirmation packet from their control channels consecutively, and the neighbors update their tables. This completes the data transmission.

3. SIMULATION MODEL

It is always desirable to obtain answers to the questions by analytical solutions. But, because of the complex nature of the system and dynamic/stochastic elements, simulation model is used to model and analyze the system. First of all, the tactical communication system under consideration has many stochastic elements such as, the call arrival rates varies for each user, the destruction of users may occur at an unknown time, the available channel capacities differs according to the geographical position of users. There are many analytical studies for queuing systems of communication networks. But the systems are mostly continuous and the state variables change continuously over time. Thus, the mathematical procedures of these analytical solutions are very complex for our network. Only steady-state results are possible for these systems. Also, it is very difficult to obtain estimates of parameters other than mean values. Because of economic reasons and difficulties creating real world conditions, it is almost impossible to exercise the systems in the field, either. Thus, to answer a wide variety of "what if" questions is a major issue. Simulation enables us to analyze different policies and system alternatives in our study. Simulation can also quantify the difference between the alternative systems and helps to see their advantages or disadvantages.

3.1. Model Development

To build the model we first observe the system and the interactions among its various components and collect data on its behavior. Then we construct a conceptual model (a collection of assumptions on the components and the structure of the system, plus hypotheses on the values of model input parameters) by carefully determining the level of details. After all, we translate the operational model into the computerized model. The stages of the model development process are given in Figure1.

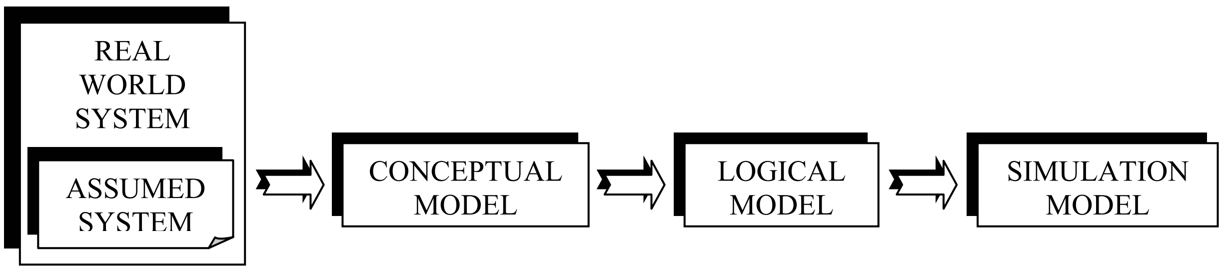


Figure 1. The stages of model development process

When developing a simulation model, determining the correct level of detail for the model is very important. The simulation model should have enough details to represent the real world system. There is always a trade off between accuracy and cost of the model and level of details. Lack of details usually causes wrong answers to the questions, while, too much detail requires more time and efforts, longer simulation runs, and it is more likely to make errors. Also, it is more difficult to debug and make changes.

3.1.1. Conceptual Model

Conceptualizing a model is one of the important phases of model development. A conceptual model provides an organized way for an analyst to document the system of interest. We create conceptual models of these real world systems to examine the essential components and structures of the real world systems under consideration. Then the basic elements of this simulation model are determined by the certain characteristics, components and the structure of the assumed system. During conceptualization, we gather data about the systems, and then we construct the logical model (flowchart) to show relationships among the elements of the model. Conceptual model contains elements of the real system, which should be included in our model. These include events, entities, attributes, exogenous variables, endogenous variables, operational rules, initial conditions and assumptions of the system. The basic elements of the proposed simulation model is given below:

Entities. An entity is an object of an interest in the system, which requires an explicit representation in the system. In our system, entities are voice calls, messages, live video files and other data files.

Attributes. Attributes are the characteristics of an entity. Our attributes are source node, destination node, source RAP, destination RAP, maximum hop number and call duration.

Events. An event is an instantaneous occurrence that changes the state of the system. The events of the system are destruction of nodes, call request, call establishment and clear request.

Activities. An activity is a time period in which the state of an entity does not change. The activities of the system are call establishment and data transmission.

Input Variables. Input variables are number of MSTs, number of PSTs, number of RAPs, velocity of nodes, direction of nodes, weather and terrain conditions, call duration.

State Variables. State variables of the system are state of MSTs, state of PSTs and state of RAPs.

Performance Measures. Performance measures include following: Number of rejected calls because of insufficient data channels, number of rejected calls because of unreachable destinations, number of terminated calls because of unreachable destinations, total number of calls, ratio of Terminated Calls, average message delivery time, average call establishment time, unit utilization, channel utilization, ratio of unreachable destinations (ROUD: the ratio of number of the calls rejected since the destination is not in the coverage area of allowed number of relay units over total number of calls) and ratio of blocked calls (ROBC: the ratio of number of rejected calls because of insufficient radio resources over total number of calls). The last two performance measures are important, since as these ratios get higher, the users of the system will have difficulties to establish a communication link with the destination nodes, even in some cases they cannot communicate with some of them.

We have also made some assumptions in the model. These are:

- All units are synchronized in time.
- Every unit has a unique identification number, which is known by other units.
- All links are bi-directional.
- Units detect the existence of a neighbor or a link failure within a finite time by a link layer protocol.
- Velocity of a unit is uniformly distributed between 0 and 8 kilometers per hour.
- Units cannot go out of the region defined for every hour of simulation.
- The lost packets over a link are transmitted and received again by a link layer protocol, so that transmission is completed in the call duration time.
- Packets sent in control channels are received correctly by the neighbor units in transmission range of the source node.
- There is no electronic attack measure of the enemy.

3.1.2. Logical Model

Logical model shows the relationships among the elements of the model. We construct the logical model of the messaging system of a brigade via flowcharts. A flowchart is a pictorial summary of the flows and decisions that comprise a process. It has several advantages in constructing the model such as functioning as a communication and planning tool, providing an overview of the system, defining roles, demonstrating interrelationships and promoting logical accuracy.

3.1.3. Simulation Model

We write the code of simulation model by using the Arena 7.0 simulation program [3]. There are many simulation packages that are used for modeling communications networks. Arena software is a general-purpose simulation language, that is, it can also be used for modeling manufacturing systems, for combat modeling or for modeling communications networks. It is also a powerful and flexible tool in creating animated models and offers reasonably good simulation output process. The major advantage of general-purpose languages is their ability to model almost any kind of communications network, regardless of its complexity. Their possible drawbacks, as compared to some simulators, are the need for programming expertise and possibly the long time spent coding and debugging that is associated with modeling complex networks [7]. Hence, to develop the model was a challenging task during our study.

3.2. Input Data Analysis

The communication system that we model is a new system and it is not tried in a war condition or in an exercise that we know. Hence, it is not possible to collect required input data for our system. But, in a data network, it seems reasonable to assume that the arrival process can be described as a Poisson process. Thus, we use exponential distribution for the call interarrival times. For the call duration times, we used uniform distribution, since it provides a good approximation when it is known that the service time is random, but no information is available about the distribution [4]. We obtain the parameters of the distribution functions by interviewing the military experts. Some of the data points are taken from the army field manuals that are written according to the war experiences. In the future applications, as we gather new data sets, the input data analysis techniques discussed in Law and Kelton [5] can be employed to find correct distribution functions for random variables.

3.3. Model Verification and Validation

Verification and validation is one of the most important stages of a simulation study, since any conclusions derived from the model will not have any meaning unless the model verified and validated. We verify and validate our model by using the following techniques and considering the principles of Balcı [6] for all steps of our study.

3.3.1. Verification of Model

Model verification is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications. In other words, by using verification techniques we will check the translation of the conceptual model into a correctly working program. We use the tools such as tracking, debugging and animation to verify the model.

3.3.2. Validation of Model

Model validation is the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model [8]. In validation process, we would like to see that the proposed model for our system is really the accurate representation of the real system. Only after the model is validated the evaluations made with the model can be credible and correct. We use the techniques such as sensitivity analysis, face validity and fault/failure insertion test to validate our model. The results are presented in Table 1. As expected the model produced invalid behaviours for both cases.

Table 1. Results of fault/failure insertion test

Performance Measures	Values for Typical Model	Values for Fault Insertion Test	Values for Failure Insertion Test
ROUD	0.0074	0.0011	0.082
ROBC	0.0106	0.025	0.379

4. DESIGN AND ANALYSIS OF EXPERIMENTS

In this section, we model messaging system of a model brigade in an attack operation. We first determine number of replications needed to achieve a desired accuracy in simulation experiments. Then we measure the system performance and finally implement factorial design to explore the significant factors and their effects. We begin the statistical procedures by determining number of replications needed to achieve a desired accuracy on the estimates of the performance measures. We use sequential procedure with relative precision criterion to determine number of replications [5]. The specific objective of the procedure is obtain an estimate of μ with a relative error of γ ($0<\gamma<1$) and a confidence interval of 100(1-α) percent. The two-stage procedure is as follows:

Step 1. Make n_0 replications (more than two) of the simulation and set $n = n_0$

Step 2. Compute $\overline{X}(n)$ and $\delta(n,\alpha)$ where, $\delta(n,\alpha) = t_{n-1,1-\alpha/2}\sqrt{\dfrac{S^2(n)}{n}}$ is the half-length of the confidence interval.

Step 3. If $\dfrac{\delta(n,\alpha)}{\left|\overline{X}(n)\right|} \le \gamma'$, use $\overline{X}(n)$ as the point estimate of μ and stop. This ratio is an estimate of the actual relative error. $\gamma' = \dfrac{\gamma}{1+\gamma}$ is the adjusted relative error to get an actual relative error of γ .Else make one more replication and go to Step 2.

The two main performance measures that we will evaluate are ROBC and ROUD. We choose the initial sample size as 10 and $\gamma = 0.10$ for both of the performance measures and simulate the system for one day length. The averages and variances for each performance measure are presented in Table 2.

Table 2. The averages and variances for each performance measure

Performance Measure	ROBC	ROUD
$\overline{X}(n)$	0.0106	0.0074
$S^2(n)$	3.32 E-06	1.59 E-06

We find that we need to make at least 10 replications for ROBC and 12 replications for ROUD to achieve the desired accuracy. Then we decide to make 15 replications of simulation model. After determining the number of replications to achieve the desired accuracy we construct the confidence intervals for ROBC and ROUD. In our case α =0.05.

4.1. Evaluation of System Performance

To evaluate the system performance, we conduct 15 simulation runs, and analyse the results. The values of average of 15 runs for different various measures are given in Table 3.

Table 3. Results of average of 15 runs for performance measures

Performance Measure	Average
Total number of calls	3215.7
Number of blocked calls	34.2
Number of blocked messages	15.67
Number of blocked voice calls	3.46
Number of blocked video transmission	9.13
Number of blocked other data	5.93
Number of unreachable destinations	23.9
Number of terminated calls	0.67
Average call establishment time	1.91 sec.
Average call duration time	47.71 sec.

When we evaluate the system performance, it seems that the system does not have a serious problem. Approximately one percent of calls are blocked because of insufficient resources that are an acceptable value for a communications network on the battlefield. Also, the value of ratio of unreachable destinations is evaluated as in good standards. While investigating the results of simulation runs, we see that the system is significantly affected by live video transmission. The plot of ratio of blocked calls by data types is presented in Figure 2.

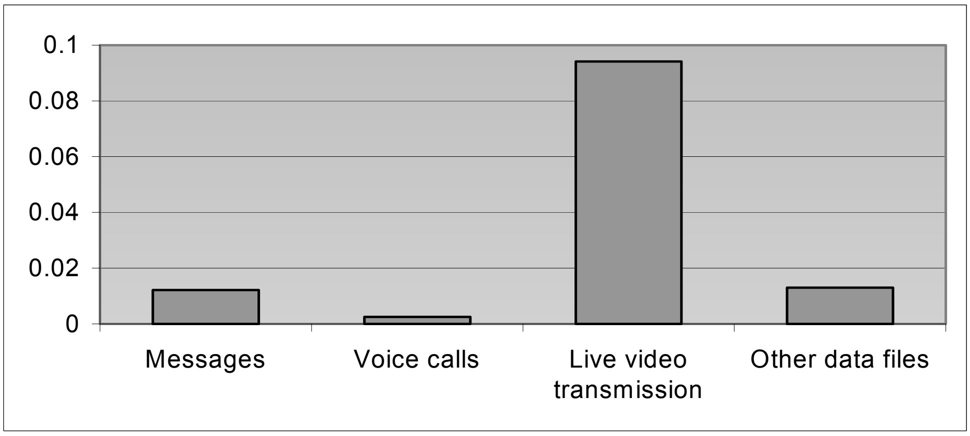


Figure 2. ROBC values for different types of data

Since, live video transmission needs an important part of resources (24 data channels), over nine percent of live video transmission is blocked. Voice calls have the smallest ROBC value since this type of data use only two channels of system resources. Since live video transmission has the greatest ROBC value, we examine the system performance in the absence of live video transmission to see the effect of this type of data on performance measures. We see that all the messages are sent to their destinations without any type of blocking in the absence of live video transmission. We also investigate ROBC values for different types of units. The results of ROBC values by types of units are presented in Figure 3.

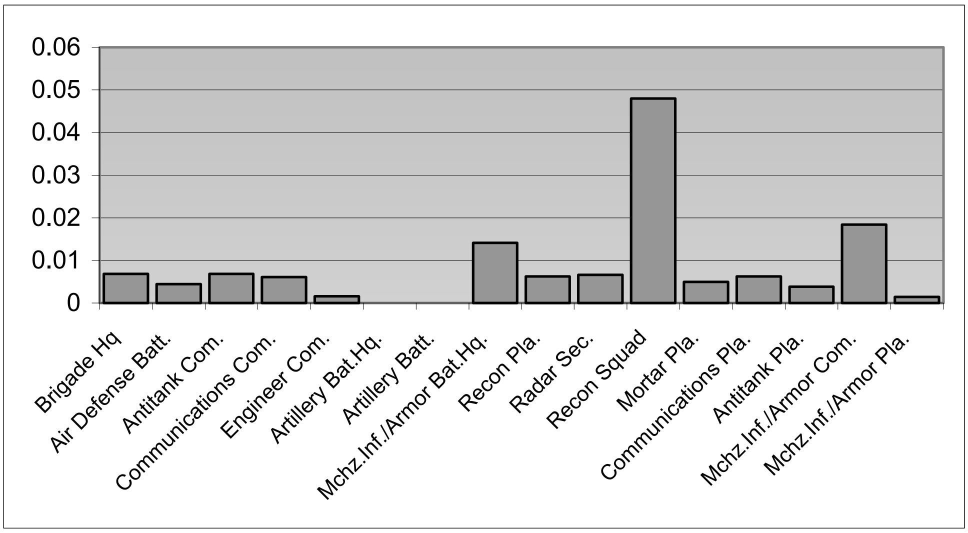


Figure 3. ROBC values for different types of units

The reconnaissance squad has the greatest value of ROBC. The second greatest value belongs to mechanized infantry and armor companies. In the system, only these units transmit live video. The mechanized infantry and armor battalions are the third in terms of value of ROBC since they realize the greatest data transmission in the system.

4.3 2^k Factorial Design

To study the effects of the factors on performance measures and the interactions between factors, we use factorial design. A special type of factorial design is 2^k factorial design, which is widely used in experiments involving several factors. We implement 2^k factorial design for the model to determine the effects and possible interactions of factors on system performance considering performance measures. In our study, there are five factors under consideration. An explanation of factors and their levels is given below.

Factor A: In the existing system, the brigade has five mechanized infantry battalions and two armored battalions. We determine the high level as a typical brigade organization. To examine the effects of different number of users on the performance measures, we decrease the number of users in RAP-2 and RAP-3 by removing a mechanized infantry battalion from RAP-2 and an armored battalion from RAP-3 as the low level of factor.
Factor B: At high level of Factor B, we increment the arrival rates messages twice of typical conditions. Low level represents normal conditions.
Factor C: At the low level of the factor, the units move at a speed of 4 kph and the brigade moves 24 kilometres per day. At the high level, mobility is high. Units move at a speed of 16 kph, and the brigade moves 72 kilometres per day.
Factor D: In bad weather and terrain conditions, the transmission range of units will decrease. We decrease the transmission range of MSTs and RAPs as the half of their actual range at the low level of the factor.
Factor E: At the low level of this factor, when the data channels are insufficient the call requests are rejected. At high level, when the data channels are insufficient, the call requests are buffered, and if the

data channels are available, the call request is confirmed. The timeout values for request are 15 seconds for voice calls and video transmission and 60 seconds for messages and other data.

4.3.1. Implementation of ANOVA

We implement analysis of variance (ANOVA) to find out which factors and interactions have significant effects on the system performance. We run the model for 32 design points. To achieve independency, we run each of the 32 design points with different seeds and different random number streams. First, we check the homogeneity of variances and normality assumptions, which are to be satisfied to implement ANOVA. We have 32 design points, and we test the following hypothesis.

$H_0 : \sigma_1^2 = \sigma_2^2 = \sigma_3^2 = ... = \sigma_{32}^2$

H_1: Above is not true for at least one σ_i^2

To check homogeneity of variance assumption, we applied Bartlett's and Levene's test. These tests are widely used to diagnose the inequality of variances. The result of Barlett's test is given in Table 4 and results of Levene's test are given in Table 5. The assumption of homogeneity of variances is satisfied for ROUD and ROBC in both tests.

Table 4. Bartlett's test result for ROBC and ROUD

Performance Measure	ROBC	ROUD
S_p^2	3.617 E-06	3.272 E-06
Q	19.313	18.073
C	1.0238	1.0238
X_0^2	43.437	40.647
$X_{0.05,31}$	45	45
Test Result	**Do not reject**	**Do not reject**

In Levene's test, a low significance value generally less than 0.05 indicates that the variance significantly differs between groups. The assumption of homogeneity of variances is satisfied for both performance measures.

Table 5. Levene's test results for ROBC and ROUD

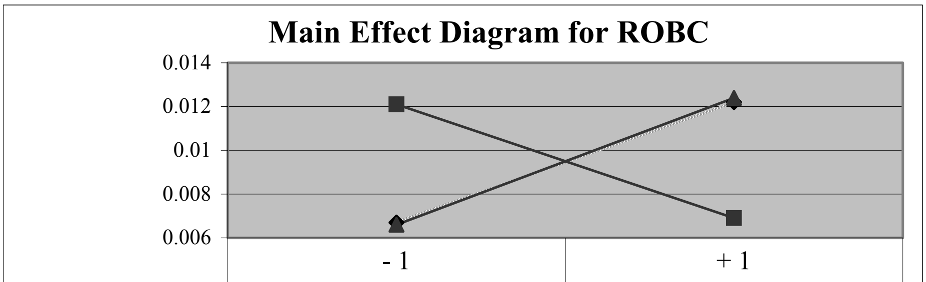
Performance Measure	F	df1	df2	Significance Value	Test Result
ROBC	1.219	31	448	0.197	**Do not reject**
ROUD	1.007	31	448	0.459	**Do not reject**

To check normality assumption, first, we compute residuals using regression model. Then, we construct a histogram of residuals. If the normality assumption is satisfied, then this plot should look like a sample from a normal distribution centered at zero. We also construct a normal probability plot of the residuals. Another procedure to check normality is to construct scatter plots of residuals. This plot of residuals should not show any obvious pattern. We also check scatter plot of variances. We see that there is no obvious patterns or structures in these plots.

Also, note that appearance of a moderate departure from normality does not necessarily imply a serious violation of the assumptions. Since the F test is only slightly affected from moderate departures from normality, we can say that the analysis of variance is robust to the normality assumption. But, gross deviations from normality require further analysis [9].

4.4. Evaluation of Main Effect and Interaction Effects on ROBC

We use SPSS software package to implement ANOVA. Then, we plot the main effect and interaction effects diagrams to evaluate the results. The SPSS output of ROBC performance measure is given in Appendix E. There are three significant factors and four two-way interaction effects on the performance measure. The main effect diagram is shown in the Figure 4.



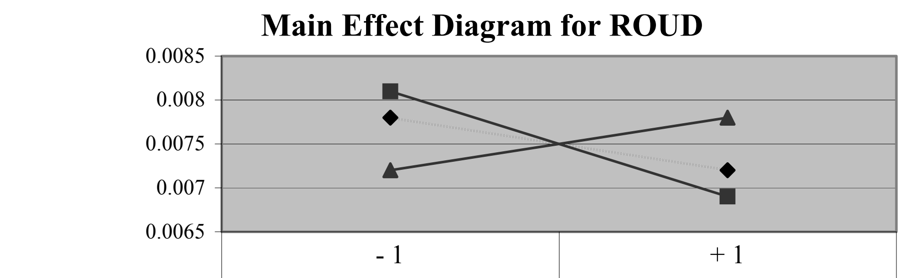
	- 1	+ 1
Factor A	0.0067	0.0122
Factor B	0.0066	0.0124
Factor E	0.0121	0.0069

Figure 4. Main Effect Diagram for ROBC

The significant factors are factor A, B and E. Factor E has an effect that decrease the value of the performance measure while the other significant factors have increasing effects. When a user has a buffer, if there is not sufficient data channel to confirm the call request, it does not immediately reject the call. The call request is buffered during 15 seconds for voice calls and video transmission and 60 seconds for messages and other data files. If there exist sufficient number of data channels in this period, the call is confirmed. Otherwise call is blocked. This causes a significant decrease in number of blocked calls. The effects of factor A and B cause an increase in the value of ROBC, since the data channel utilization will increase in both cases. Factor C and D have not significant effects on the ROBC. The units on the battlefield are positioned close to each other and they move in their responsibility area. Hence, mobility does not affect the distance between them significantly. Bad weather and terrain conditions will affect the transmission range, but this decrease in the transmission range will not affect the number of hops from source to destination significantly. We have also four significant two-way interaction effects. These are between factors A-B, B-C, A-E and B-E. First interaction effect is between factor A and B. Both factors have effects that increase the value of ROBC. When the brigade has five battalions, utilization of data channels increase. If we increase the traffic rate while the data channels are highly utilized, increase in ROBC will be more significant. Thus, the slope of the performance measure when one factor is at its high level is more than the slope of the performance measure when the factor is at its low level. Another interaction effect is between factor B and C. Factor B has an increasing effect on the performance measure and factor C has not a significant effect. The other interaction is between factor B and E. The factor B has an increasing effect while the effect of factor E is decreasing. The factor E has a more significant effect on ROBC. When the utilization of data channels is high, the factor E affects ROBC more. The interaction between factor A and E can be explained in a similar way as interaction between B and E. The results show us that as the number of messages increase in the system, the system robustness goes down. Since the distances between the units of the brigade in an offensive operation are not long, the effect of mobility is not significant. But as the distances get longer, this effect will increase.

4.5. Evaluation of Main Effect and Interaction Effect on ROUD

We plot the main effect and interaction effects diagrams of ROUD performance measure to evaluate the results. There are three significant factors on the performance measure. The main effect diagram is shown in the Figure 5.



	- 1	+ 1
Factor A	0.0078	0.0072
Factor C	0.0072	0.0078
Factor D	0.0081	0.0069

Figure 5. Main Effect Diagram for ROUD

The significant factors are factor A, C and D. Factor A and D have effects that decrease the value of ROUD while factor C has an increasing effect. The weather and terrain conditions are the most significant factor. Mobility factor is more significant than the type of brigade. As the mobility increase, the distance between the source and destination node will also increase such that the destination is not reachable in allowed number of hops. The other significant factor is the type of brigade that has a decreasing effect on ROUD. As the number of subscribers of the same RAP increase, the network will have a more connected structure. The more connected network structure will cause a decrease in the value of ROUD. The traffic rate and existence of buffer is not significant because they do not make any change in the distance between users. The only significant two ways interaction effect is between factor A and D. When factor D is at its low level, the effect of factor A is more significant.

5. CONCLUSIONS

In this study we develop a simulation model for a messaging system of a model brigade. We have two main performance measures under interest that are ROBC and ROUD. We determined the effects of different factors on performance measures and finally construct different scenarios to examine the effects of different types of operations on performance measures. When we evaluate the system, the system performs well for all performance measures. It seems that the system does not have a serious problem. The multi-hop capability of units extends the connectivity of the network. The effect of the higher usage of multimedia files is negative on the system performance. Units should send this type of data, when the network is less congested.

We perform 2^k factorial designs to determine the effects of factors on performance measures and implement ANOVA to determine the factors that have significant effects on performance measures. The significant factors on ROBC are type of brigade, message traffic rate, and existence of buffer. The results show us that as the number of messages increase in the system, the system robustness goes down. Since the distances between the units of the brigade in an offensive operation are not long, the effect of mobility is not significant. But as the distances get longer, this effect will increase. The significant factors on ROUD are type of brigade, mobility and weather and terrain conditions. Type of brigade and weather and terrain conditions have effects that decreases the value of ROUD while mobility has an increasing effect. The weather and terrain conditions are the most significant factor. The only two-way interaction effect is between type of brigade and weather and terrain conditions. As the number of units in the same area increase, the network will be more connected because of the multi-hop capability of units. The distance between units is an important factor for this performance measure.

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Modeling Command & Control Centers

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ABSTRACT

To date, legacy simulations of all operation levels have not dealt with the C4ISR aspects of the battle space. Nearly all of these simulations assumed either perfect C4ISR capability on both sides or employed some unjustified approaches to take C4ISR capabilities of the opposing forces into account. These approaches to modeling C4ISR did not make it possible to evaluate C4ISR systems and their contribution to the mission effectiveness.

Currently, especially developed countries are well aware of the potential contributions of robust and integrated C4ISR systems to overall military effectiveness and working on concepts like Information Warfare, Network Centric Warfare and etc. Most of these countries are spending large portions of their budgets on procuring / developing C4ISR systems. C4ISR systems are inherently very complex and as a result it is very hard, if not possible, to develop architecture, concept and tactics with pure analytical approaches. At this point, simulation seems to be the most suitable candidate for this kind of C4ISR analysis.

This paper will present a detailed description of the Command, Control, Communication and Computer Analysis Tool (C4AT) that is currently being developed by the Turkish General Staff Scientific Decision Support Center. When the first version is completed, the tool will be capable of simulating peace time activities of the strategic and operational level command and control centers. The second version will also have the ability to simulate and analyze crisis and conflict time activities of the similar command and control centers.

1.0 INTRODUCTION

The study of complex systems that have many actors and their interactions often becomes too complex for a mathematical model. Agent-based modeling is a tool to study these kind of systems. The tricky part of this modeling tool is to specify the environment, agent-knowledge model and the interactions between the agents.

A software agent can be defined as any type of software entity that fulfills the basic concepts of agency. Ferber defines the properties of a software agent as follows [Ferber 1999] :

- An agent is capable of acting and modifying its environment
- An agent can communicate with other agents in the environment
- An agent has intentions
- An agent controls some local resources

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- An agent is capable of perceiving its environment to a limited extent
- An agent has only a partial representation of its environment
- An agent possesses skills and can offer services

The need for simulating a group of agents in an environment leads to the development of Multi-Agent Systems (MAS). Weiss gives the following characteristics of multi-agent environments [Weiss 1999]: They provide a basis for specifying interaction and communication protocols; they are mostly open and have no centralized designer; they contain autonomous and distributed agents that may be cooperative or self-interested. Instead of defining MAS characteristics, Ferber reports elements that comprise a MAS. These elements are environment, objects, agents, relations, operations, and operators. Environment is a space in which every object of the MAS resides. Everything in the environment is an object. An agent is also an object in the environment that satisfies agency requirements. Relations link objects to each other in the environment. Operations are the actions that agents can perform in order to modify the environment and to achieve their goals. Operators can be described as the laws of the environment. Operators are basically the reactions of the environment to the actions taken by agents. Constructing a MAS requires detailed models of these elements.

MAS simulation is a new solution to the problem of imitating complex adaptive systems. Axelrod describes MAS simulation as “a way of doing thought experiments,” the goal of which is to enrich our understanding of fundamental systems [Axelrod 1997]. He contents that the goal of MAS simulation is not to find exact solutions to real world problems, but rather to provide insight into complex systems that conventional approaches cannot model. Therefore, modeling every aspect of the system is unnecessary. Axelrod proposes the famous army slogan, “Keep it simple, stupid” to the MAS simulation designers. Otherwise, the change in the outcome of the simulation cannot be linked to any particular variant in the simulation and hence makes simulation useless. However, one should also be very careful in deciding which aspect of the real world should not be included in the simulation. Omitting a key component of a system from the simulation may result in meaningless, undesired outcomes.

command and control centers are complex organizations in nature. They contain many co-operating actors (agents), each having different personalities, roles, and goals. Within these organizations, many time critical processes take place in parallel which makes it very hard to keep track of the interactions between the agents. These interactions are also highly depended on the work load, which is determined by the outer organizations. With these properties, any command and control center can be thought as a multi agent system.

Since it is too hard, if not impossible, to model such a complex system with conventional modeling and simulation techniques, agent-based approach has been chosen to study command and control centers, and a generic agent-based simulation engine is implemented.

Section 2 describes the generic simulation engine and the methodology for creating a new project. Section 3 deals with the communication devices and their working principles. Section 4 introduces the environment design. Section 5 presents detailed information on the agent architecture. Section 6 is intended to demonstrate a scenario in execution. Finally, Section 7 gives a summary of the study and its results.

2.0 THE SIMULATION ENGINE

In order to implement our agent-based tool for simulating command and control centers (ComConCent), first a generic simulation engine independent of the tool was developed. The generic simulation engine is actually a single software class (*TBtnEngine*), which is used as a base class and inherited in order to create our analysis tool, C4AT. The functions of the *TBtnEngine* is as follows:

- Enabling creation and modification of the project environment and the scenario,
- Managing environment and scenario files (save and load operations)
- Defining scenario agents incuding their behavioral characteristics and tasks based on the developed High Level Task Management Script (HLTMS) and Behavioral Transition Networks (BTN) architecture.
- Accepting insertion of any project specific resources (properties, methods, classes, data, etc.)
- Allowing agents to access all the resources of the project through a C-like run-time interpreter developed within the scope of the study.
- Running scenario with a selected time management mode (event based, real-time, and constant time interval).

As mentioned above, TBtnEngine can be customized using object inheritance, thus new projects can be created by just over-writing the bold lined functions depicted in Figure 1. *TBtnEngine* controls the whole simulation activities through these functions. For instance, when a new agent needs to be created, the engine calls the *CreateAgentProc* function (pointer) to let creation of a project specific agent instance.

```
class TBtnEngine

          TBtnEngine        ( TObjectBaseClass * includes, TCreateAgent createAgentProc );
virtual ~ TBtnEngine        ( );

TCreateAgent CreateAgentProc;

virtual void SaveToStream   ( TStream * stream );
virtual void LoadFromStream ( TStream * stream );

virtual void SimStarted     ( );
virtual void SimStopped     ( );
virtual void SimAdvanced    ( double simTime, double deltaTime );
virtual bool InLOS          ( TAgentBaseClass * agent, TAgentBaseClass * target );

void SaveToFile             ( AnsiString filename );
void LoadFromFile           ( AnsiString filename );

void Start                  ( );
void Pause                  ( );
void Stop                   ( );
void Advance                ( );

TAgentBaseClass * AddAgent  ( );
TAgentBaseClass * FindAgent ( AnsiString name, int * index = NULL );
...
...
```

Figure 1. TBtnEngine Class Interface: new projects can be created by customizing the bold lined functions

The critical point in customizing the engine is to use *TObjectBaseClass* as a base class to all the new classes. This base class enables registering any variables and functions in real time to let the run-time interpreter access project resources. To extend the flexibilty of customation, *TBtnEngine* and all of its sub-classes are also inherited from this class. With the customized engine, C4AT, the geographical location of the scenario can be set, the ComConCent buildings including their interior can be designed, the communication devices can be introduced and the agents can be defined. The C4AT architecture and its class definition are shown in Figures 2 and 3 respectively.

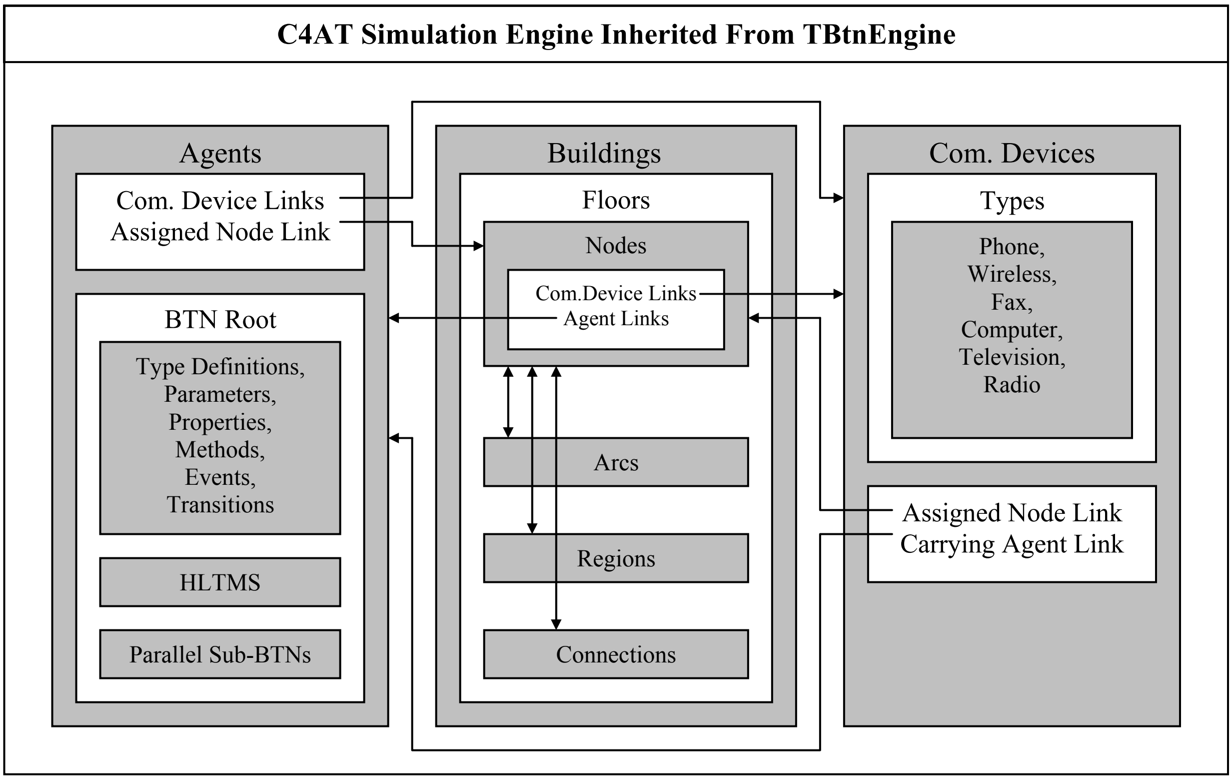

Figure 2. The general architecture of the C4AT

```
class TC4ATEngine : public TBtnEngine

      TComDevices  * ComDevices;
      TBuildingSet * BuildingSet;

                TC4ATEngine       ( TObjectBaseClass * includes, TCreateAgent createAgentProc );
      virtual ~ TC4ATEngine       ( );

      virtual void SaveToStream   ( TStream * stream );
      virtual void LoadFromStream ( TStream * stream );
```

Figure 3. C4AT Simulation Engine Class : The bold lined objects are extension of the project, and the rest are functions modified in order to customize the engine

3.0 DEFINING THE COMMUNICATION DEVICES

The communication devices that are employed in command and control centers can be categorized as: phone, radio, fax, computer, and multimedia (television, radio, newspaper, etc.). Since, speed has generally higher priority than information security in peace time operations, the phone is the most preferred communication device in such operations.

Consequently, we started the development of communication devices with the phone. For the time being, the first version of the telephone communication framework is completed. In this framework, the phone is designed to be in one of the following states: available, waiting for dial tone, ready to dial, calling, connected, busy, disconnected or ringing.

The agents are designed in such a way that they can detect if a phone is in-use, if not, they can pick up the phone, wait for the dial tone, dial the number and take different actions depending on the communication state (calling, connected, busy or disconnected) and finally hang up the phone.

An agent can only use three kinds of phones categorized by their ownership: the ones he carries on (e.g. cellular phones), the ones he is responsible for (e.g. at home, at the office), and the ones that are owned by his group members. When a phone rings, the agents around the phone can hear the ring. If it is one of the phones he carries on or he is responsible for, he immediately tries to pick up the phone. If it is owned by one of his group members, then he waits for a short period of time and if no one picks it up, he tries to do it, and else no reaction is performed.

4.0 DESIGNING THE ENVIRONMENT

The simulation environment consists of a set of buildings and their interior. The location of each building is described by its geographical coordinate in lattitude and longitude. Following the definition of the location, the building images are automatically displayed on the screen if corresponding data exists in the environment database. A sample building exterior is illustrated in Figure 4.

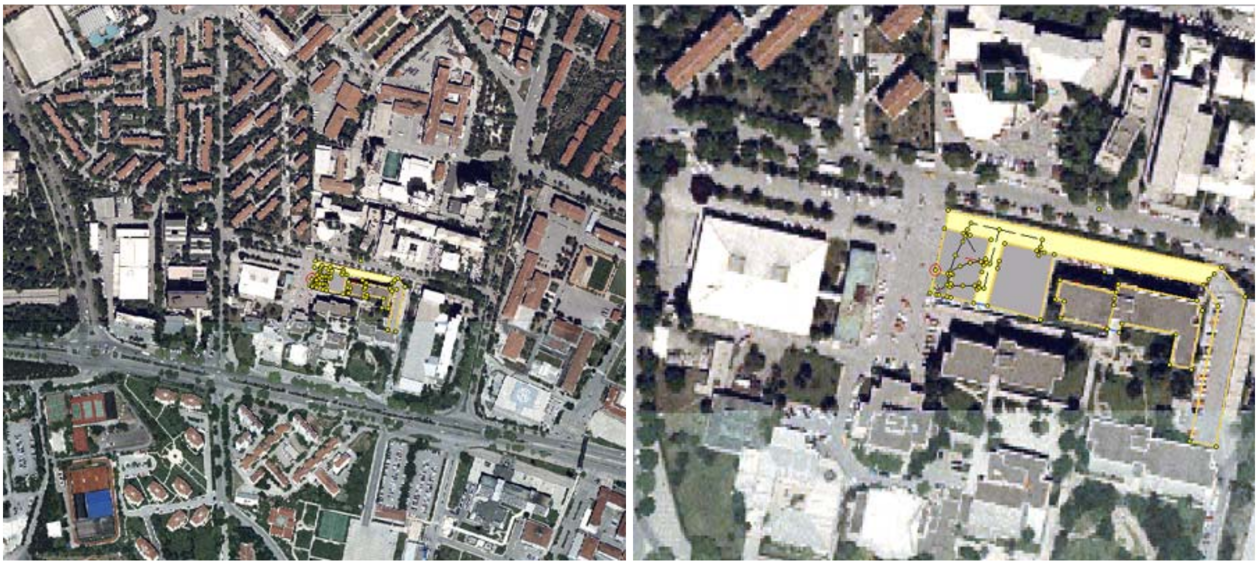

Figure 4. A building exterior visualized with two different zoom levels

In order to create building models, a building editor is developed. This editor is capable of designing buildings by creating each floor and their connections with other floors. Floors contain nodes (connectors, tables, chairs, etc.), arcs (walls, windows, doors, etc.), regions (room floors, roofs, etc.) and connections (walking routes, relational links, etc.). A sample building interior design is demonstrated in Figure 5. Every object in the environment is positioned on one of the nodes. Connections are used for defining possible routes that could be used for navigation and specifying relations between objects. For example, when an agent percepts that a phone is ringing, he first tries to go to a neighbor node of the table on which the phone is located by searching the connections to the table.

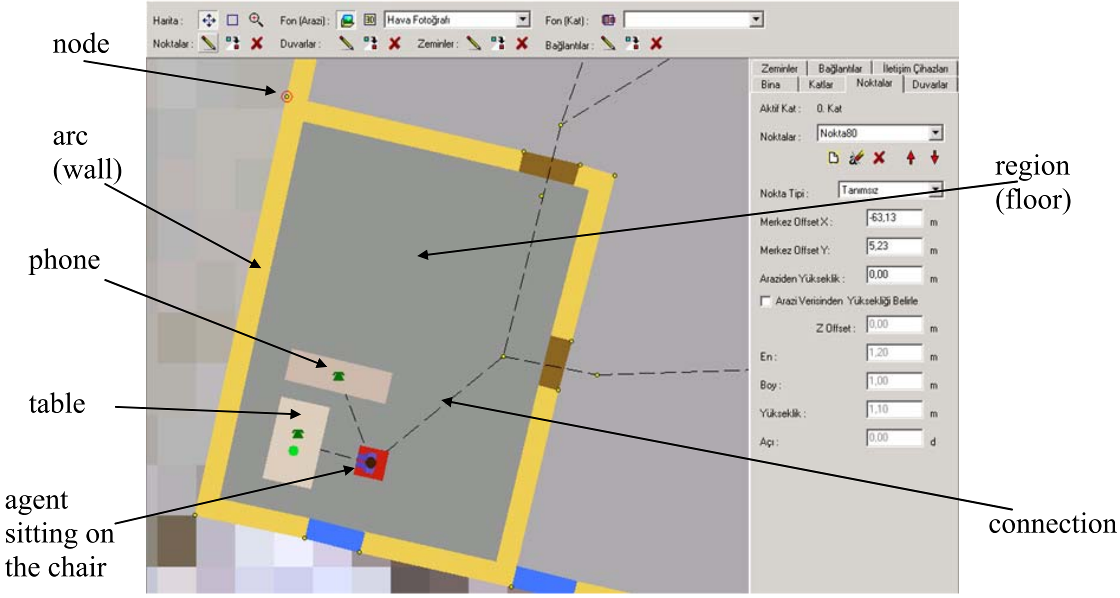

Figure 5. A building interior : The buildings are designed as set of floors.

5.0 DEFINING THE AGENTS

The behaviors of the agents are modeled using Behavioral Transition Networks (BTN) and a sub-feature defined within BTN structure called High Level Task Management Script (HLTMS). BTNs [Houlette 2000] are firstly introduced by game developers to increase practical aspects of defining behaviors. Later on, they became more common and used in many other fields. In fact, BTNs are just a specialized approach based on State Transition Diagrams and Harel Diagrams (statecharts) [Harel 1988, Ghezzi 1991, Rosenblum 1994, Budgen 1994], and defined using nodes and state transitions between nodes. Nodes may possess sub-nodes, resulting a type of hierarchy.

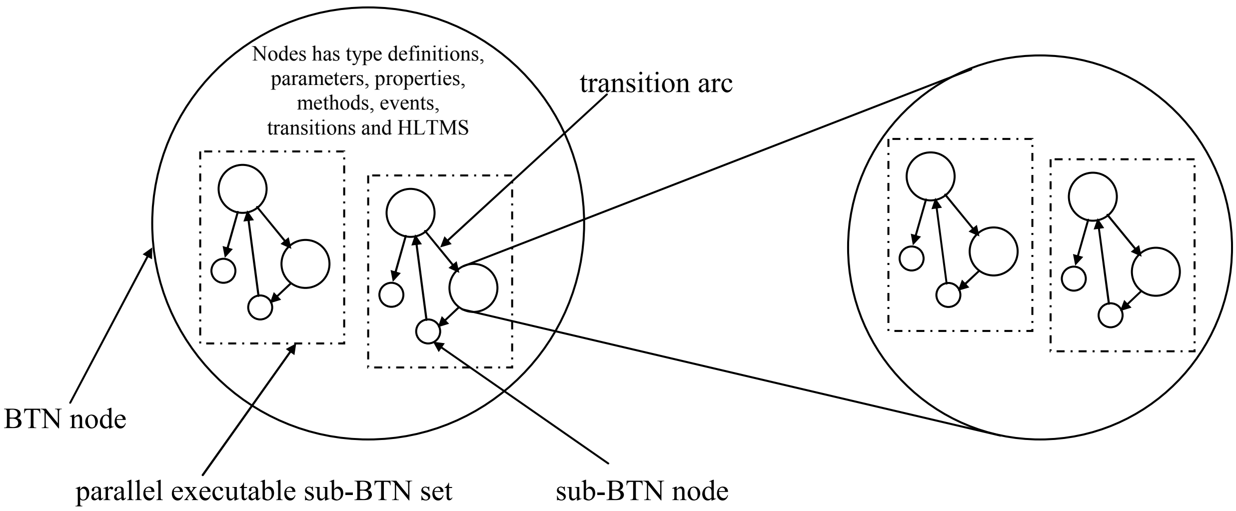

Figure 6. General Architecture of a BTN

A modified version of BTN framework is developed for *TBtnEngine*. This framework has some additional features such as parallel executable sub-BTNs and a HLTMS. General architecture of our BTN framework is illustrated in Figure 6.

Each BTN node has its type definitions, in-going transition parameters, out-going transitions (in a hierarchical case based structure), properties, methods, events, and a HLTMS. BTN nodes are activated, executed and deactivated by transitions, HLTMS and events: *on enter*, *on leave*, *on message* and *on process*. Each event is a script which is executed by the run-time interpreter. All the events but *on process,* are executed from start to end at once. Execution of *on process* events can be interrupted by using *wait* or *breakcode* statements defined in the script.

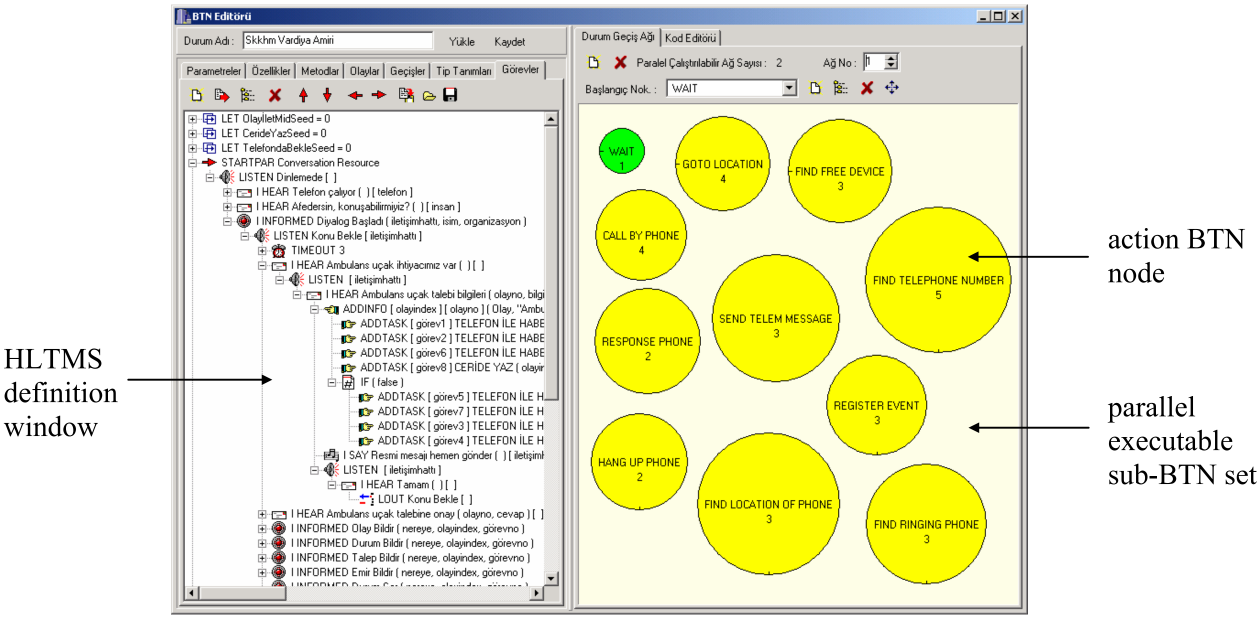

Figure 7. A root BTN sample for agent behavior modeling

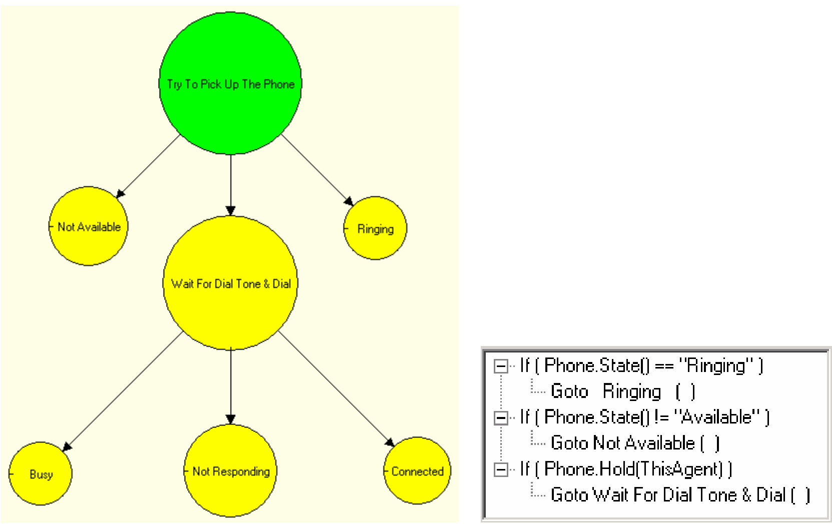

Figure 8. "CALL BY PHONE" action BTN (left), transitions of "Try To Pick Up The Phone" (right)

Each agent has a set of behaviors assigned to him, which are defined in a single BTN node (root BTN). Therefore, customizing that BTN node (defining HLTMS, adding sub-BTNs, etc.) also changes the behavioral characteristics of the agent. In our agent design, first level BTNs, the ones directly owned by root BTN, are generally used for action modeling such as calling by phone, going to a location, etc. A root BTN and an action BTN are demonstrated in Figures 7 and 8 respectively. As seen in Figure 7, there are no transition arcs between action nodes, because actions are fired by HLTMS.

HLTMS is actually a hierarchically defined script, the statements of which can be executed sequentially or in parallel. Some of HLTMS statements and their descriptions can be viewed in Table 1.

Table 1. Some of the HLTMS statements

Statement	Description
STARTPAR	Starts a parallel execution (starts executing sub-script under STARTPAR in parallel)
CANCELPAR	Terminates a parallel execution
WAIT	Waits for a specified time period
LET	Assigns a value to a variable. If variable is not defined, it is created
ADDINFO	Inserts an information/data item into BTN node
ADDINFORM	Inserts an information message into a parallel execution
ADDTASK	Inserts a task into a parallel execution
REMOVETASK	Removes the active task of a parallel execution
DELAYTASK	Delays execution of the active task of a parallel execution
I SAY	Sends a voice message to an agent or object (phone)
I DO	Triggers an action
DORESULT	Captures the result of an action
LISTEN	Starts listening for perception messages, information messages and tasks
I HEAR	Used inside a LISTEN statement. Enables receiving voice perception messages
I INFORMED	Used inside a LISTEN statement. Enables receiving information messages
I SELECT	Used inside a LISTEN statement. Enables selecting from tasks. The task with highest priority is always selected.
LOUT	Backtracks to the start of a specified LISTEN statement

An example HLTMS for responding a phone call is illustrated in Figure 9. In the sample, the execution is started from the very first line. When a *STARTPAR* statement is reached, a parallel execution for the sub-statements called "Conversation Manager" is started. After that, the execution continues and reaches to another *STARTPAR*, which starts another parallel execution called "Task Manager". And finally the execution reaches to a *LISTEN* block that contains a single *WAIT* statement, which causes an infinite loop. When "Conversation Manager" is executed, it starts listening for voice messages. If a phone rings, the agent gets a voice message informing him that the phone is ringing. This causes the addition of a "Respond Phone" task to the parallel execution called "Task Manager". When "Task Manager" is executed, it starts listening for tasks. When it encounters a "Respond Phone" task, it starts executing the sub-statements of the task. The agent first identifies the phone to see if he has right to pick it up. If so, he finds the location of the phone, goes to that location and picks up the phone. If the connection is established, the agent says hello to the remote side and waits for a reply. If he gets the reply, he insert an information message to "Conversation Manager" to inform the starting of the conversation and waits until the phone conversation is terminated. Then, the "Conversation Manager" captures the information message and guides the conversation. For simplicity, the conversation part is skipped. After the termination of conversation, the conversation manager inserts an information message to "Task Manager" informing that the conversation is over. In this case the "Task Manager" hangs up the phone and starts waiting for another task.

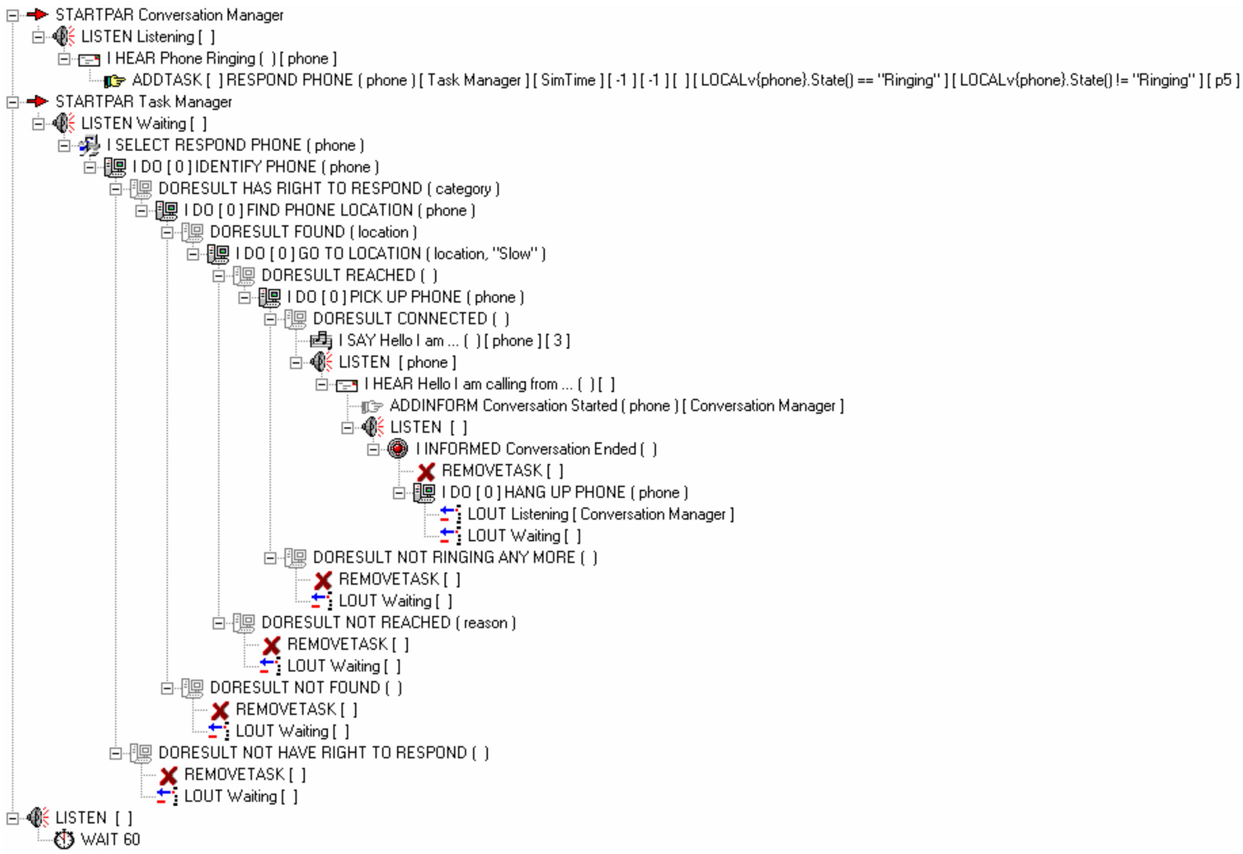

Figure 9. A sample HLTMS for responding a phone call

In order to avoid implementing complex perception algorithms, which are beyond the scope of this study, we assumed that the agents can perceive (hear and see) any object that is at the same floor and within 10 meters range.

Following the development of voice and visual perception mechanism, we were able to form a methodology for task distribution among agents. Although there are many complex ways to introduce collaboration among agents [Axelrod 1997, Feber 1999, Ercetin 2001], we used a simple but effective model, which reflects nature of command and control hierarchy. An agent informed of a task (event, request, order) generates a set of sub-tasks to meet the requirements of the main-task. Following task decomposition, additional sub-tasks for task distribution management are inserted. For instance, if the task is an event, the agent generates sub-tasks of the event and an additional task for reporting to the superior. If the agent could not manage to inform his superior, he starts doing tasks that are not strictly depended on the completion of informing the superior. When he manages to give the report to the superior, the sub-tasks not completed yet are fully canceled, because because they will be distributed by the superior. Then the superior generates a list of sub-tasks for himself and for his sub-ordinates, and distributes the sub-tasks to his sub-ordinates considering the work load.

The path planning of agents for navigation is another challenging problem to be solved. Path planning is defined as searching for a set of state transitions to reach to a goal location from an initial location. It is cetegorized in to two: off-line [Deloura 2000] and real-time [Undeger 2001a, Undeger 2001b] path planning. Off-line path planning has the advantage of generating high quality routes, but takes much CPU time and not suitable for highly dynamic environments. On the contrary, real-time path planning algorithms give poor solution quality, but is highly interactive and very adaptive to changing conditions.

The technique employed in our study is off-line path search through the connection graph, which is discribed in Section 4.

6.0 RUNNING THE SCENARIO

Once the behaviors and tasks of agents are modeled, the next step is to run the scenario. This function is directly supported by *TBtnEngine*. The *TBtnEngine* allows selection of time management metodology and simulation time multiplier. There are three main time management modes: event based, real-time and constant time interval. In the event-based time management mode, the events are tracked in the order that they will occur and the simulation is advanced to the nearest one. Therefore, the scenario is run as fast as possible in this mode. This mode is currently under development. The second mode is real-time, in which the time is advanced in parallel with the real-time (or a multiplier of real-time). In this mode, there is a possibility that the advance of a single step of the simulation will take more time than desired. For this reason, this mode is divided into three sub modes: unlimited time steps, constant time steps, upper bounded time steps. If unlimited time steps mode is used, the simulation time steps continue until all the related code is executed. If constant time steps mode is preferred, the execution is interrupted and passed to the next step when the specified constant time is exceeded, else a delay is inserted to reach the specified constant time. In upper bounded time steps mode, the execution is interrupted and passed to the next step if specified constant time is exceeded. The last time management mode, constant time interval, is generally used in debug mode, which ignores real-time and advances simulation time with constant time step, no matter how much time the step actually takes.

After starting the simulation, the simulation state can be observed on visualization window and messages are printed on the message window. The environment, the location and body posture of agents, the state of devices and the messages exchanged are all shown on visualization window. The messages (BTN execution messages, HLTMS execution messages, and run-time interpreter messages) are printed to the message window. The visualization and message windows are shown in Figure 10.

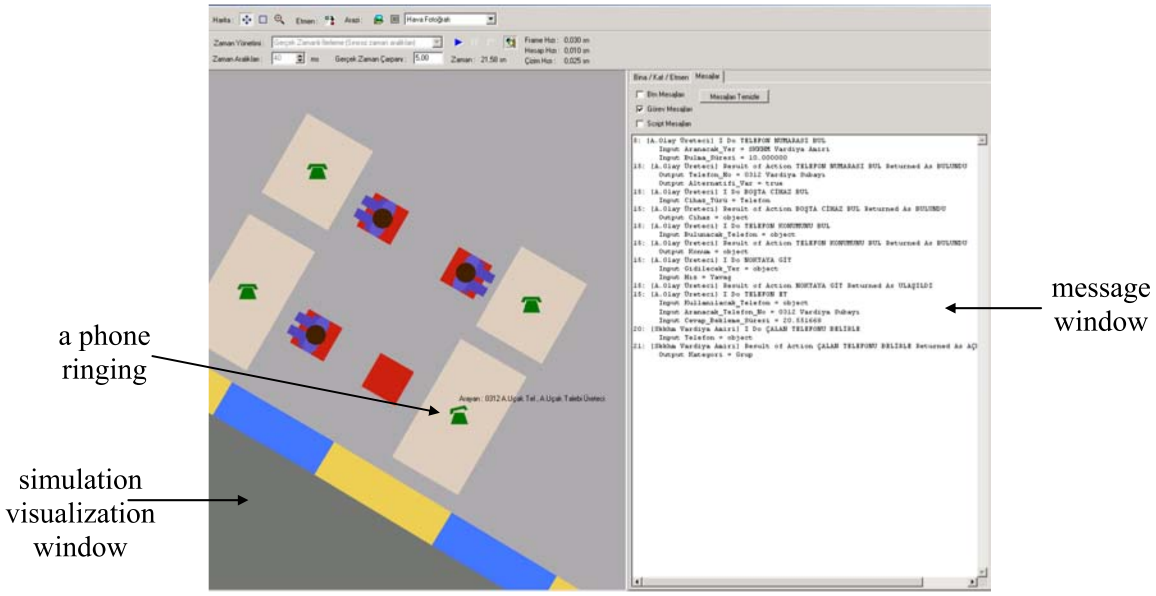

Figure 10. A snapshot of the simulation in execution

7.0 CONCLUSION

In this paper, we have proposed a simulation framework and a simulation tool for modeling command and control centers. First, we have started with the definition and properties of software agents, and clearly stated the reasons for developing our framework on top of agent based systems. Later, the generic simulation engine designed to realize the framework, and the customized engine for C4AT have been presented in detail. We have mostly focused on our agent-based system, which employs Behavioral Transition Networks and a newly proposed approach called High Level Task Management Script. For C4AT analysis toolkit, a communication framework and an environment design is developed and a sample scenario is generated. The first version of our implementation has given promising results for modeling a larger scenario that covers all the functions of a ComConCent. Thus, we are currently studying on the tool for defining new agent behaviors and tasks to improve the system.

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Essential Preconditions for Coupling Model-Based Information Systems

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1. INTRODUCTION

Command, control, communication and intelligence (C3I) systems as well as simulation systems belong to the class of model-based information systems. This is obvious in the case of simulations, which are always based on models. But C3I systems, too, have to be based on models of the corresponding real world processes in order to manage the tremendous complexity of military systems. The latter becomes immediately clear when thinking of terrain representation in form of military maps, which are a perfect example for reliable models. However, since model designers necessarily abstract and simplify reality according to their own perception and conceptions, models can significantly differ in several aspects. Experiments with the high resolution combat simulation system COSIMAC (developed at the Institute for Applied Systems Science and Operations Research (IASFOR) at the University of the Federal Armed Forces Munich, Department of Computer Science) and some modules implementing basic C3I functionality (command and control modules) have shown that there are some essential preconditions for coupling such model based information systems. Our results indicate that technical and syntactic preconditions (addressed by HLA and ATCCIS, for example), which have been in the focus of interest for almost a decade, are not sufficient to guarantee a successful interaction. The crucial tasks are to ensure that syntactical structures are attributed with the same meanings in all involved models and that the same actions are triggered by identical orders and reports. These findings have been confirmed during a study we performed for the German Armed Forces addressing the standardization of command and control components for different Army simulation systems. As a consequence of the importance of meanings and triggered actions we have chosen a linguistic approach to understand the problems of interoperability, which is based on the idea of successful communication between models / model users. That might seem a bit strange at first sight, but regarded from the perspective of the model designer, the coupling of models is in fact a sophisticated kind of communication with his counterpart.

In linguistics one generally presupposes the existence of a technical communication channel (which is so important in computer science) and concentrates on the three semiotic aspects of language which are syntax, semantics and pragmatics. Linguistics provide a perfect framework for investigations into the meaning of interactions, since the whole point of setting up a theory of semantics and pragmatics is to provide a systematic account of the nature of meaning. Communication is successful if and only if sender and receiver have common knowledge on all semiotic aspects. Based on our experiments, this paper discusses several examples of failed coupling at the level of semantics and pragmatics. Generalizing these results we conclude that there are at least four compulsory preconditions (1-4) for C3I/M&S interoperability and one desirable precondition (5), by name:

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(1) Automatically processible data (syntactical standards)
(2) Standardized algorithms (for data fusion and aggregation)
(3) Similar or at least compatible model development approaches
(4) Collated triggering of actions
(5) Standardized GUI and uniform SW ergonomics.

Since the mere presentation of coupling problems stemming from a limited amount of models would be too anecdotic and idiosyncratic to be convincing, the paper first introduces a general framework (sections 2 – 5) in which the examples presented in chapter 7 fit as illustrations of the basic ideas. Section 6 provides the reader (non-insider) with some fundamental information about ground combat simulation systems.

2. MODEL BASED INFORMATION PROCESSING SYSTEMS

From a general point of view information processing systems can be distinguished into direct and intermediate control information systems (see Figure 1): Most of the (artificial) information processing systems used today are embedded into real systems in which they operate as control units. Their task is to ensure that the state transition of the real system stays within a given trajectory. Such information processing systems exert direct control over the system they are part of (β^S -function in Figure 1). Examples for this kind of information systems are electronic devices like anti-lock braking systems or electronic traction control systems in cars. On the other hand there are information processing systems that do not manipulate the real system states directly. One possible reason for this is that in these systems the space of possible state is much to great to be held under control directly. Via abstraction and idealization (φ-function in Figure 1) a model of the real system is created. Within this model one tries to achieve control over the dynamics of the assumed states (Z^M, and not Z^S). In general, this is done by postulating causal dependencies between different states. After execution of the model (β^M-function) it is necessary to "retranslate" from Z^M to Z^S (ψ-function). Now it is possible to check in the real system whether the predictions of the model are valid ore not. If they are, it is assumed that M is a helpful model of the system S and $\psi \bullet \beta^M \bullet \varphi$ is regarded to be a good substitute for β^S.

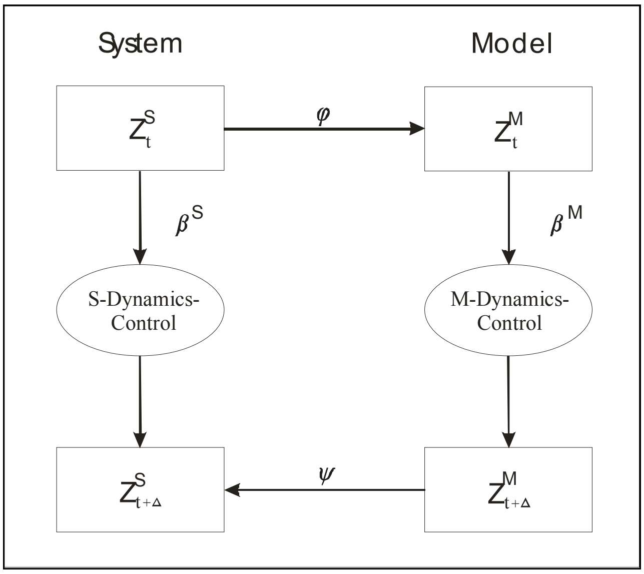

Figure 1: Direct and intermediate control of dynamics in systems and models

It is obvious that all simulations are examples of model based information processing systems. Combat simulation systems are almost perfect instances of this class. But C3I systems too, have to be regarded as model based. Starting with the company level and intensifying above it, military command is based on models of the real combat situation. The direct processing of observations can only be the foundation of combat control on the weapon system and (to a certain extent) platoon level. Working with tactical symbols on terrain maps is as much model based as simulation.

3. MODELS AND THE NEED FOR COMMUNICATION

Whenever models *A* and *B* of systems **A** and **B** are combined, it is necessary to ensure that both models share a common conceptual picture *C* of the supersystem **C** (see Figure 2).

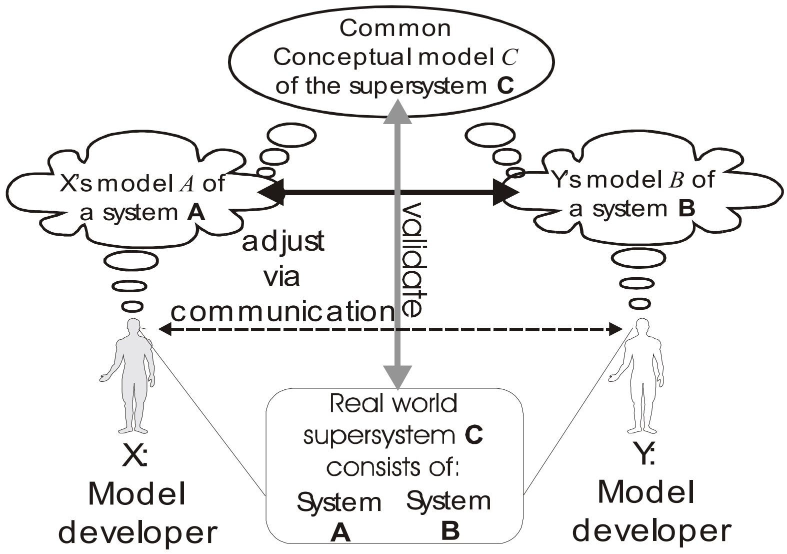

Figure 2: Models, communication and validation

Whereas it is clear that the supersystem **C** has to be a superset of **A** and **B** (at least if one does not deliberately omit aspects of the real world modelled in *A* or *B*), it is not self-evident that the common conceptual model *C* is likewise only a superset of *A* and *B*. In fact, in most cases it is necessary to start with the intersection set of *A* and *B* and extend or adjust it in order to create a *common* conceptual model. As an example let us consider two different ground combat simulation models and their terrain representation. The supersystem terrain **T(C)** has to be a superset of the real terrains **T(A)** and **T(B)** modelled in *A* and *B*. The exact definition of this superset should not be a challenging problem even if **T(A)** and **T(B)** are completely separated and we have to define an additional connecting "corridor". Unfortunately, the models of the terrains *T(A)* and *T(B)* can differ so much from each other that even if **T(A)** and **T(B)** are identical, a common terrain model *T(C)* is extremely hard to develop. Let us assume that *T(A)* is a vector model and *T(B)* a grid model. There is no common conceptual model for these two types of terrain representation. One has to give up one of them or integrate both approaches into both systems. Even with two grid models serious problem can occur if *T(A)* and *T(B)* do not distinguish between the same terrain types (forest, urban, open terrain, water, etc.) or do not use the same algorithms to compute trafficability values from terrain type, slope and weather conditions. Using the formalism introduced in the previous chapter, the problem can be stated as follows: It is relatively easy to combine two system state sets Z^{S1} and Z^{S2} but in order to combine two model state sets Z^{M1} and Z^{M2}, the different abstraction and idealization functions φ^1 and φ^2 (and subsequently β^{M1} and β^{M2} and also ψ^1 and $\psi^{2)}$ have to be reconciled. Whereas set theory provides powerful means for the first task, there are no general methods for the second one, since abstraction and idealization are in themselves not approachable by formalization. Consequently, finding a common conceptual model for two models developed from different persons X and Y requires intensive communication between X and Y about φ^1, φ^2, β^{M1}, β^{M2} , ψ^1 and ψ^2. Despite this challenge it is very assuring that the basis for validation, the real supersystem **C** is generally much less disputable than *C*. Thus, checking whether the coupling of the models was successful or not normally has a sound foundation (essential for validation). Reconsidering our example, one can easily prove if a vehicle movement possible in your coupled model would have been possible in the real terrain.

4. A LINGUISTIC PERSPECTIVE ON MODEL COMMUNICATION

After realizing that personal communication is almost inevitable in every model coupling project it becomes essential to ensure successful communication. Unfortunately, there exists no universal formal language that could grasp the whole variety of abstraction and idealization possibilities. Thus, at least some part of the communication process between the modellers will be natural language communication. The special branch of science that deals with successful natural language communication is linguistics, which differentiates syntax, semantics and pragmatics of an utterance in language. Since most people are familiar with syntax and semantics but not with the linguistic concept of pragmatics a short description may be helpful. In the semiotic trichotomy developed by Charles Morris, Rudolph Carnap, and C. S. Peirce in the 1930s, syntax addresses the formal relations of signs to one another, semantics the relation of signs to what they denote, and pragmatics the relation of signs to their users and interpreters [1-3]. The central rationale for pragmatics is that sentence meaning (semantics) in natural languages vastly underdetermines speaker's meaning (intentions). The goal of pragmatics is to explain how the gap between sentence meaning and speaker's meaning is bridged [4].

In "linguistics words" (which sometimes seem a little bit convoluted), pragmatic information concerns facts relevant to making sense of a speaker's utterance of a sentence (or other expression). "The hearer thereby seeks to identify the speaker's intention in making the utterance. In effect the hearer seeks to explain the fact that the speaker said what he said, in the way he said it" [5]. Because the intention is communicative, *the hearer's task of identifying it is driven partly by the assumption that the speaker intends him to do this*. The speaker succeeds in communicating if the hearer identifies his intention in this way, for communicative intentions are intentions whose "fulfilment consists in their recognition" [6]. In other and much simpler words, pragmatics is concerned with whatever information is relevant, over and above the linguistic properties of a sentence, to understanding its utterance [4]. It should be mentioned that even Noam Chomsky, the world's most famous and influential linguist has stated that "a general linguistic theory must incorporate pragmatics as a central and crucial component" [7].

As an <u>example</u> consider a mountain walk of an experienced climber and his friend, who has always stayed in flat land. During the walk the climber shouts "Stone" and expects his friend to seek for shelter. Unfortunately, his friend doesn't even raise a hand. On which communication level occurred the error? We can assume that the flatlander heard what his friend said (physical transmission), understood the phoneme "stone" and mentally translated it into the correct word "stone" (syntactic level) and knew what a stone is (extensional meaning of the word, semantic level). Hence the fatal error must have occurred on the pragmatic level as an *failure of communicating the demand of action.*

It is obvious that the line between semantics and pragmatics cannot be absolutely definite and that some aspects of contextual information and other connotation could be placed into the semantic bucket, too. (In the example, one could argue that the semantic of the word "stone" in the context of mountain hiking has to be extended.) But in general it is not recommended to extend the borders of semantics, because it quickly leads to person dependent ambiguity in semantic definitions (What if a geologist shouts stone during a mountain walk? Is he delighted or terrified?).

However, taking the nature of pragmatics into consideration, it is no surprise that it has been omitted in computer and many other sciences. The general guideline in all natural and technical sciences is to reduce subjective factors down to zero. Hence scientists from this research areas seek to find or define a pragmatics-free (context, connotation and especially individual opinion free) experimental system. Unfortunately, that approach has strong limitations whenever human behaviour and communication have to be regarded. To a certain extent developing models for complex dynamic systems is always a subjective endeavour, especially when taking into consideration the different purposes, scales, user modes and resolutions of models of such systems, the degrees of freedom within each of these aspects and the necessity to tailor each model to fit the purpose.

So far the linguistic aspect of pragmatics has been emphasised. The following sections changes the focus to the relationship between models and pragmatics. As an introduction to this relationship consider the definition of semiotic qualities of conceptual models (see Table 1) given by [8].

Table 1: Definition of semiotic qualities of conceptual models (Lindland et al. 1994)

Syntactic quality	The degree of correspondence between a conceptual model and its representation.
Semantic quality	The degree of correspondence between the conceptual model and the real world.
Pragmatic quality	The degree of correspondence between the conceptual model and its (individual) interpretation.

One of the central dogmas of modern computer science is the demand for unambiguous programs that **can be used without any additional context information (information hiding)**. Especially for component-based software architectures this requirement is said to be essential. Taking this dogma literally implies that documentation of programs mustn't be essential for model understanding and application but only (extremely) helpful. Ideally the program/module itself (as a sequence of statements in a programming language) should contain the whole meaning/sense of the underlying (conceptual) model.

I do not doubt that from the perspective of software engineering this dogma is completely justified. There actually is a huge amount of software that fulfils this black-box criteria. However, as far as I can see, these programmes are of a very fine granularity, and very often monofunctional. The simplicity of these components in terms of degrees of freedom is the reason why the black-box approach works. However, to base a general hierarchy of domain specific components - that finally would lead to complex multifunctional modules - on a black-box architecture is most probably an illusion of current software engineering. **In complex military, economic or logistic simulation systems the code vastly underdetermines the modeller's ideas and intentions**. Therefore, model documentation in natural language and additional verbal communication, despite all their disadvantages of ambiguity and connotations, are essential parts of the interaction among model developers and users.

5. THE PROBLEM OF HIDDEN ASSUMPTIONS

The hard part of developing simulation systems of complex dynamic systems is not code generation but appropriate modelling which is mainly abstracting and idealizing. If all abstraction and idealization a modeller has used in building a model were easily discernable or well documented, it would be possible - in terms of the framework introduced in chapters 2 and 3 - to exactly define and understand the φ- , β^{M-} and ψ-functions underlying the model. Unfortunately, almost every modeller uses assumptions which are not documented and hard to reengineer from the executable model if one does not know what to look for. In general, one gets to know about hidden assumptions the hard way: the model-federation produces nonsense and it is extremely difficult to explain it. Naturally, it would always be possible to make a special assumption transparent. The problem is, that in the modelling of complex systems there are so many assumptions involved that completeness can hardly be assured. In addition, there are assumptions which are taken for granted and therefore not documented. But "self evident facts" are sometimes quite disputable.

Something that is often hidden in the description of ground combat simulation systems is the scope of the perceived situation. Every unit and every command level has a perceived situation, which differs from the real situation according to their current information respectively information deficits. In reality, this "picture of the battlefield" is convoluted mix of own perceptions, messages, orders, situation updates from higher and lower echelons, adjacent units and even civilian information sources. It is extremely difficult to keep all this pictures consistent. Therefore, there is always a *scope* of the perceived situation of a unit which denotes which and how many other units currently share a consistent variant of it. Because of its complexity the real development and updating process of the perceived situation is simplified within the simulation systems. How this simplification is done depends on many factors, especially purpose and resolution of the simulation system. When we tried to find it out for the combat simulation systems listed in the next chapter, not one model documentation was sufficient and I venture to doubt that all the modellers of these systems were fully aware of the problem.

It may be a subjective opinion, but I am absolutely convinced that it is impossible to reduce hidden assumptions in models of complex dynamic systems down to zero. As a consequence there will always be the need for an intensive test and adjustment phase after a *technically* successful coupling of such models.

6. GROUND COMBAT SIMULATION SYSTEMS AND C3I SYSTEMS

Over more than two decades scientists at our Institute (IASFOR) have analysed ground combat simulation systems used in the German and other armies (for example: JANUS, HORUS, GESI/SIRA, PAPST, KORA, IRIS [9-12] and designed and implemented own simulation systems (see below). The level of complexity of these models reaches from simplified test simulation systems and relatively simple simulations based upon cellular automata (ZEGA and ZELGAT [13]) up to full scope aggregated land battle models (KOSMOS [14]) and high resolution ground combat models (BASIS [15]), COSIMAC-P, COSIMAC-WS [13]), which are in terms of system theory [16] extremely complex. In addition, we have recently compared three of these systems (GESI, HORUS and our own model COSIMAC) in a study. The goal of this study was to assess the feasibility of standardized command and control (C&C) modules for high resolution combat simulation systems. The study was also part of the preparing efforts towards a new German ground combat simulations system ("SimSys Einsatz Heer"), which is intended to be integrated into the new German C3I environment. Before discussing the results of this study, a short introduction to ground combat simulation systems is given.

Ground combat simulation systems (GCSS) are a very heterogeneous class of models ([13], [17]), nevertheless they all share some fundamental parts. Every GCSS has to model the following **aspects of combat**:

1. terrain and environmental representation,
2. movement,
3. attrition,
4. transportation (at least of ammunition),

5. communication and
6. reconnaissance.

Generally, GCSS are discrete event simulations based upon an event queue. The GCSS mentioned above aren't real time simulations, anyway internal time management is essential. If the GCSS is used for analysis in a closed simulation it is necessary to add

7. command and control modelling,

which shouldn't be a part of the central simulator - for reasons explained in [13].

The major distinctions between the models, beside different **purposes** (acquisition, decision support, analyses, training)**, scopes** and **user modes** (closed simulation or interactive)**,** is their level of **resolution**: the level of detail at which the real world system and its behaviour is modelled. Referring to [18] and [19] resolution in combat simulation systems has six "components":

1. temporal scale,
2. spatial scale,
3. processes,
4. entities,
5. attributes and
6. dependencies.

This classification is arguable, but useful to illustrate the degrees of freedom for the modelling. It has been shown (see for example [18]) that it is far from trivial to ensure consistency between models of different resolution.

In terms of the theoretical framework introduced in section 2 different purposes, scopes, user modes and resolutions all tend to increase the deviations between the φ–functions and consequently between the β^M-functions of two models. Thus, even with completely congruent real systems **A** and **B** (**C** = **A** = **B)** deviations between the models *A* and *B* can be too great to find a *satisfying* common model *C*.

The development of command and control (C&C) modules for GCSS is not only the precondition to reduce the amount of interactive operators in command post exercises, it is also a precondition for using GCSS as decision support tools. Moreover, it is essential to realize that the integration of GCSS into C3I systems will only be successful, if the C&C-modules in the simulations operate on the same principles as the automatism applied within the C3I system. Otherwise, the simulation of courses of action in advance would be very dubious. As an example consider the problem of data fusion. The same algorithms that process (connect, condense, countercheck etc.) real messages in C3I systems have to be applied within the simulation in advance in order to keep its situation update consistent.

7. ESSENTIAL PRECONDITIONS FOR SUCCESSFUL COUPLING OF MODEL BASED INFORMTION SYSTEMS

With the basic considerations presented in the previous sections it is now possible to highlight the results of the research at our institute and to establish the essential preconditions for successful coupling of model based information systems. In the following it should be reminded that the conclusions presented here are drawn from projects within the simulation domain. It has to be admitted too, that the expertise of our institutes (IASFOR and ITIS) covers more of this domain than of the traditional Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) domain.

7.1 Technical aspects

We have coupled different versions of our own COSIMAC combat simulation systems via the HLA, CORBA and a simple self-made TCP/IP interface within a local area network. Although all of these solutions had some drawbacks, most of the basic *technical* functionality for interoperation could be provided. There are major differences between these solutions when it comes to additional services (authorisation, time management, security etc.), flexibility and maintainability, but these differences also show that different approaches *can* do the job. So far, there is no technical framework for interoperation that comprises all advantages and avoids all drawbacks – and maybe such a framework will never exist. But the reassuring result of our own research is that most of the problems with imperfect technical architectures are surmountable. Therefore, if there is any real problem for coupling simulations and C3I systems at the technical level, it will be the problem of unification on the basis of a not disputed standardisation.

7.2 Syntactic aspects

The first precondition for coupling model based information systems are automatically processible data (terrain, weapon systems, personal, organisational, tactics etc.) in the very straightforward sense of standardized syntactic structures that may lead to a formal military language. The range of the standard determines the range of easy interoperation. Thus, NATO-wide standards are preferable. The Land Command and Control Information Exchange Data Model (LC2IEDM) was an important step in that direction. Without a common syntax the coupling of simulations and C3I systems is hardly thinkable, since syntactic transformations between different models are much too cumbersome to be feasible within a multinational environment. The challenge on this level is put by general drawbacks of all formal languages in comparison to natural languages. First, whereas there are many different personal incentives to learn a foreign natural language, the use of a formal language has to be enforced. Second, no formal language can capture to whole expressiveness of a natural language. Third, most of the difficulties of misunderstandings in natural languages occur on the pragmatic level of communication. Such misinterpretations of persons you use a language can happen with formal languages as well. Formality could therefore evoke fallacious trust.

7.3 Semantic aspects

I have addressed technical and syntactic issues only briefly because there is so much other work done in this fields and I have to admit that we did not find out something really new in our studies for these levels. On the semantic level, in contrast, there are some challenges which have been underestimated. It is self-evident, that the semantic meanings of syntactic structures have to be defined according to common use or a predefined ontology. In general, that leads to a kind of glossary or lexicon, attributing meanings to character strings. During the efforts to integrate command and control modules into our GCSS we realized that such a lexicographic summary is not sufficient to guarantee consistent interoperation. What is needed in addition are standardized algorithms for the modelling of elementary processes like attrition, movement, data fusion, reconnaissance and communication. In order to explain this need, an illustrative example might be helpful. In high resolution GCSS it is necessary to model reconnaissance of individual combat vehicles like tanks and AFVs (Armoured fighting vehicle). This can be done with regularly "glimpses " or sector scans, with global detection probabilities or, in grid models, with individual terrain cell checks, to name just a few possibilities [17]. The algorithms behind these methods lead to different perceived situations, since detection of enemy entities will not occur at the same simulation time. However, perceived situations are the most important information for any command and control module. Hence, the reconnaissance algorithm influences the course of action chosen from the C&C module. A module devised in the context of a "glimpses" model is therefore not directly applicable to a cell check model, even if all messages and orders the C&C module gets are standardized in both models, or with other words, even if a standardized interface between high resolution GCSS and additional C&C modules exists. One can easily transfer this example to the problem of data fusion which has to be solved both in simulation systems and C4ISR systems. Different fusion algorithms will lead to different estimates of the situation. A simulation in advance using its own data fusion algorithm would differ from the real course of action perceived after using the C3I data fusion algorithm even if the initial situation would evolve as predicted. Using our theoretical model, the problem can be simplified into the following consideration: With a static lexicon of standardized terms only the φ-functions of the model building process are addressed. The dynamic processing of model states via the β^M-functions (algorithms) remains largely unconsidered.

On the other hand there are even examples that consistent φ-functions cannot be guaranteed only with semantic lexicons. A perfect example are deterministic and stochastic models based on otherwise identical representations. Let us first assume that two *simulation* systems have to interoperate. One system uses deterministic parameters and the other determines averages from a certain amount of stochastic simulation runs. It is very well known, that the value of averages highly depends on the underlying distribution. Any discrete distribution similar to the continuous probability density function sketched in figure 3 would be an extreme counterexample for the use of averages.

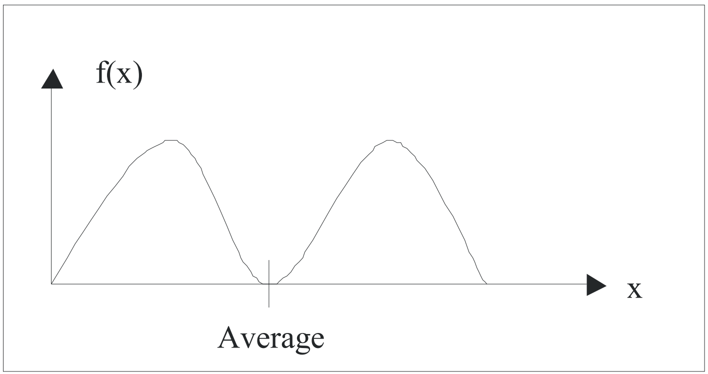

Figure 13: Sketch of a double peak probability density function (PDF)

If the stochastic simulation provides the deterministic simulation with the results of its stochastic runs in the form of such an average, further simulations within the deterministic model are almost useless. The same would hold true if we replace the deterministic simulation with a deterministic C3I system. Stochastic and deterministic models of a system are the result of two different φ-functions, which are not always compatible without further considerations (about variance for example). Similar problems occur, if discrete and continuous or event and process driven or descriptive and predicting models are connected. It is possible to couple such models in a sensible, purpose-driven way, but only with adjustments that go far beyond even a sophisticated glossary. Consequently, a third essential precondition for coupling model based information systems are similar or at least compatible model development approaches.

7.4 Pragmatic aspects

Pragmatic aspects of interoperation deal with the actions (state transitions) triggered within a person or any other information processing system after receiving, decoding and semantically understanding a transmitted information. We are all familiar with the problem of the huge variety of possible actions and state transitions a human being possess in a communication. In order to be successful in triggering the desired actions or state transitions in the receiver the human sender (speaker or writer) has to take into account the probably different attitudes, beliefs, physical skills, mental capacities, physical and emotional constitutions, social and cultural backgrounds of his counterparts. In general this is done unconsciously as a consequence of lifelong learning. Nevertheless, most of the unsuccessful communications between humans occur on the pragmatic level. The very reason for this problem is that it is relatively easy to define the semantic meaning of a word or sentence, but impossible to find a general agreement on the pragmatic influence factors attitude, belief etc.

It may seem that this problem has little to do with the challenge of coupling artificial model based information systems like simulation or C3I systems. Unfortunately, as has been shown in chapter 3 and 4, the coupling of models always involves human communication problems. Therefore it should be expected that errors on the pragmatic level can be found whenever model driven information systems are coupled. That is exactly what we find out. I do not want to discredit any of the models mentioned in chapter 6 except our own. Thus, I am not going to use these model names in the following examples.

The most striking examples of different pragmatics in GCSS we found in command and control modules. The variety of possible actions and state transitions triggered from an "immediately attack objective Z" order given to different C&C module is impressive, even in the very homogeneous context of the COSIMAC GCSS. Different programmers (within the COSIMAC project all programmers where active officers, too) assume different state transitions according to their mental picture of reality. The first variety has been introduced by the evaluation of the term "immediately". The range of possible and actually realized pragmatic interpretations spans from "abandoning all other tasks" and "immediately" start moving with available unit members at maximum speed, to the assembly of scattered unit members and regrouping, followed by a movement optimisation based on speed *and coverage*.

A similar problem has been the exact state transition after reaching the objective. Most COSIMAC programmers (modellers!) stopped the attacking units after reaching the objective and deployed them within a predefined area in order to establish an all-around defence. However, some implemented a kind of opportunity function, allowing the attacking units to progress, if (a) inferior enemy units could be destroyed or (b) tactical localities could be seized. In general, the challenge of such flexible modules (mission-types tactics) is to ensure that the higher commanders intent (presumable the part of an order which defies formalisation the most!) is always taken into account.

Which behaviour is adequate depends on circumstances and reflects to a certain extent the degree of freedom a human decision maker has in the same situation. A further refinement of the models would have been necessary to overcome this problem. However, according to the abstraction and idealization level chosen for the model there is always a limit for such extensions, especially in rule-driven modules (consistency!). Additionally, the pragmatic problems tend to increase with higher resolution, since more idiosyncrasies of terrain, situation and mission have to be regarded.

These findings which have been first realized during the development of C&C modules for the GCSS COSIMAC, have been strongly supported by research on other GCSS of similar resolution (HORUS, GESI). Even if syntactic and semantic inconsistencies could be overcome, pragmatic issues would impede many interesting and sensible interoperations. Details of this research can be found in [20].

It is essential to realize that inconsistency problems like those mentioned above are not consequences of bad modelling but consequences of the modelling of complex dynamic systems in itself.

Moreover, during efforts to integrate the human factor "willingness to take risks" in the GCSS COSIMAC we realized that the variety of possible, but unfortunately inconsistent interpretations can only be curbed by extremely simplifying assumptions which have little to do with reality.

What all of these examples clearly show is, that the actions triggered within a GCSS after receiving a semantically well defined message or order can significantly and inconsistently differ. Thus, even if we have eliminated all ambiguities through unequivocal semantic definitions model coupling can still fail. Fortunately, for most of the examples mentioned above it is possible to fix a kind of reference model with standard actions and state transitions – which is the fourth essential precondition of coupling model based information systems.

The last aspect of interoperation addressed in this paper is theoretically less compulsory than the previous ones but maybe of equal importance in practice. The briefing efforts necessary to use different simulation and C3I systems is tremendous. This labour should not be complicated by different graphical user interfaces (GUI) and other aspects of SW ergonomics. Again, a kind of standard should be designed, including the arrangement of menus, statistical information and scenario editors. Otherwise, no single user will be able to keep an overview and face validation would be impossible.

8. SUMMARY, CONCLUSION AND A CRITICAL REMARK

The successful interoperation of model based information systems is not only a technical or syntactical problem. Most of the real challenges occur on the semantic and even more on the pragmatic level. The only practicable way to overcome these challenges are strict standardisation or (and) time consuming additional test and adjustment phases with the model federations. The arguments presented in this paper have been confirmed by examples from the simulation domain. However, the author is convinced that similar experiences have been made in the traditional C3I domain.

The main conclusion for the coupling of NATO simulation and C3I systems is that the scope of standardisation should be extended to pragmatic issues, too. For that reason, it is necessary to unfold the conceptual models of the simulation or C3I systems as clear as possible.

It should be remembered that the models developed in operations research should always be tailored to solve one special problem or to fulfil one special purpose. Coupling them often implies to blur specific adaptations of the models to their original purpose. “Monolithic” should therefore not become a negative attribute in itself.

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C4ISR/Sim Technical Reference Model Applicability to NATO Interoperability

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ABSTRACT

The 1998 Computer Generated Forces (CGF) Conference included a paper [1] which proposed a Technical Reference Model (TRM) for interoperability between U.S. Command, Control, Communication, Computers, Intelligence, Reconnaissance, and Surveillance systems (C4ISR)[1] and Computer Generated Force simulations (Sim). This TRM characterized the "type of information that is necessary to pass between C4ISR and CGF systems". Since then, changes have occurred in technology for interfaces; the uses for interfaces; and the Architecture(s) upon which they are based. In addition, significant changes have occurred in the respective source and target systems that these interfaces connect, namely C4ISR systems and simulations. Finally, substantial interest has been expressed in the availability of C4ISR hosted simulation components, as well as the integration and exchange of components between the two domains. A recent Simulation Interoperability Standards Organization (SISO) Simulation Interoperability Workshop (SIW) paper [2] has proposed substantial changes to reflect the evolution of technology, supported systems, current interface practices, and near term future uses for C4ISR – M&S interfaces.

This paper briefly describes the revised version of the TRM. It suggests when and how to use the TRM in reference to NATO Command, Control, Communication, and Intelligence (C3I) system to modeling and simulation (M&S) interoperability or integration efforts. It shows the TRM's relationship to current NATO models and standards in the C3I domain, as an aid to those concerned with interoperability, integration, or standardization efforts between the two types of systems. The paper explores the use of the TRM in light of NATO interoperability efforts, and reflects on the relationship between the C4ISR/Sim TRM and NATO guidance documents/standards such as the NATO C3 Technical Architecture (NC3TA), the NATO Common Operating Environment (NCOE) Model (NCOM), and others.

1.0 INTRODUCTION

In 1998, a TRM for interoperability between C4I systems and simulations was developed and proposed to the 1998 Computer Generated Forces Conference [1]. Since first proposed, the TRM has generated a substantial amount of interest within the US C4I – M&S interface community, particularly within the Simulation Interoperability Standards Organization (SISO) Simulation Interoperability Workshop (SIW) conferences. It has been the focus of several SIW study groups intended to "formulate a broad-based technical model to describe and categorize interoperability of systems or classes of systems" [3,4,5]. The work and discussion of these groups continues, as well as their desire to "leverag[e] existing work and foster development of that TRM into a formal SISO product."

[1] C4ISR systems are the US DoD functional equivalent to NATO Command, Control, Communication, and Intelligence (C3I) systems

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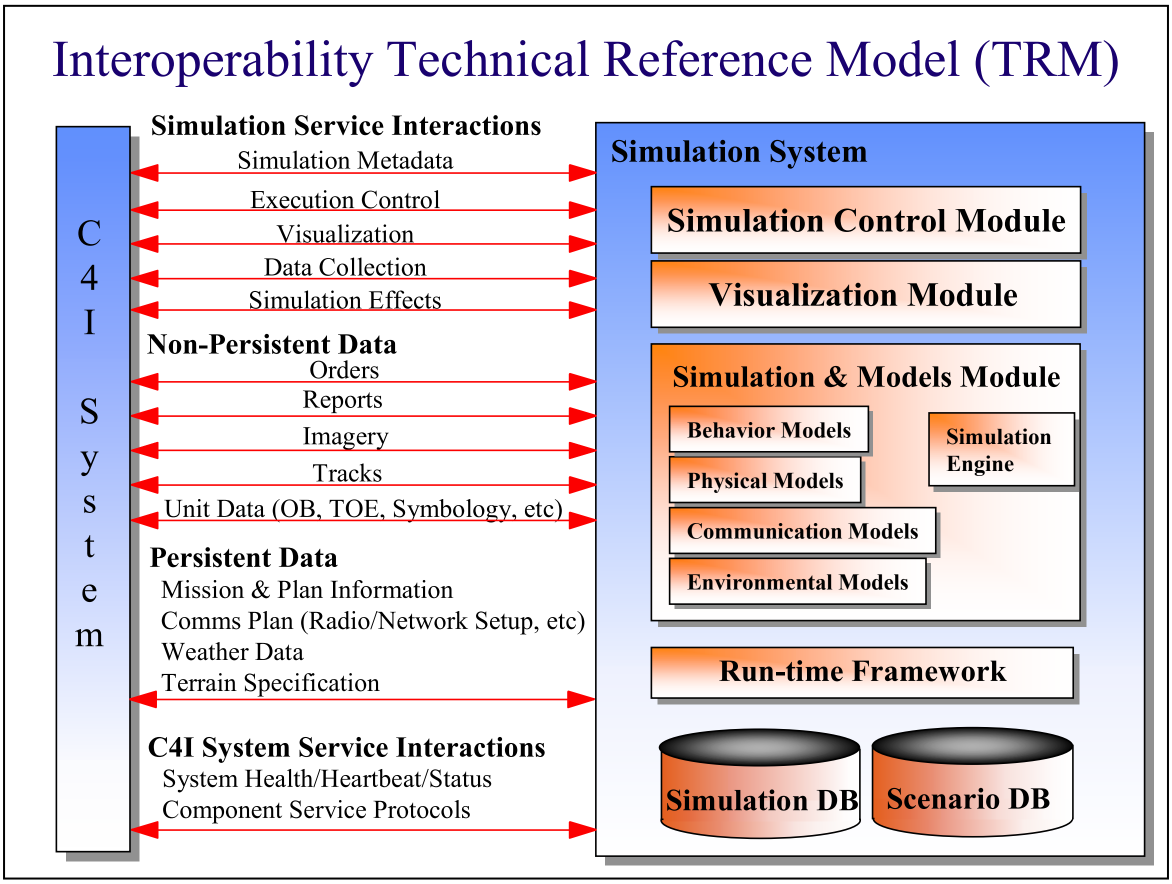

Figure 1 - C4I - M&S Interoperability Technical Reference Model

At the Spring 2003 SIW, the author proposed substantial changes to the TRM [2], as reflected in Figure 1 (Following page). These changes are being considered by the current SISO C4I – Simulation TRM Study Group, and are expected to become part of the formal C4I – Simulation TRM (C4I/Sim TRM). Section 2 of this paper provides an overview of the proposed C4I/Sim TRM, with additional detail in the source paper [2] and study group sourcebook [6].

The remainder of this paper is organized as follows: Section 2-4 provide an overview of the C4ISR/Sim TRM, Section 5 provides an introduction to various analysis sections which follow (Sections 6-9), Section 10 summarizes the result, with specific recommendations to the NATO Modelling and Simulation Group (NMSG).

2.0 C4I – M&S INTEROPERABILITY TRM OVERVIEW.

The C4I/Sim TRM is intended to be a generalized model of the components and interactions that are considered significant to efforts to establish interoperability between C3I and simulation systems/components, regardless of application for the interface effort. It is NOT intended to represent any specific simulation system, or current/future interface. Any level of detail within the C3I system has been intentionally omitted, as these systems are generously described in other documentation, such as the US DOD TRM [10,11] or NATO TRM[16 - 20]. The detail within the simulation system is kept at a high level of components that might be candidates for distribution in an architectural design. Another purpose for the high level Sim components is to suggest those that might be interchanged with C3I components as found in the NATO Common Operating Environment (COE) "basket of products". Finally, the level can be used to suggest possible candidates for component level integration, both using simulation components on board the C3I system and also using C3I components to facilitate interoperability during interface efforts. The scope of the C4I/Sim TRM is intended to allow for the consideration of component level interoperability, as well as systems level interoperability between simulation(s) and C3I system(s). The C4I/Sim TRM is intended to be appropriate whether the application for the interface is training/computer aided exercises (CAX), C3I system evaluation/test, acquisition, or simulation based decision support tools residing on (or remote from) the C3I system.

Changes in the way that C3I systems have been developed, in particular through the use of a Common Operating Environment (COE), have made them more modular or "component" based. Taking advantage of these changes, the interface community has more frequently re-used core components from C4I systems (e.g. message processors, database management systems, comms modules) in interfaces to reduce costs and improve interoperability.

The goal of the TRM is to assist programs in achieving more effective levels of portability and interoperability in the following ways:

By providing a consistent and common lexicon for description of interoperability requirements between diverse systems

- By providing a means for consistent specification and comparison of system/service architecture
- By providing support for commonality across systems
- By promoting the consistent use of standards
- By aiding in the comprehensive identification of information exchange and interface requirements

Although the TRM is based on current and past project experiences, it is intended to be evolutionary and flexible enough to support future needs, regardless of range of requirements or architecture configuration. Users are encouraged to use the TRM for guidance, and extract only those elements that support their specific project needs.

3.0 TRM INTERACTION CATEGORIES

Connecting the separate systems (or components) are *Interactions,* which are collected together into 4 categories. These categories of information exchange include service-oriented groupings for each domain's systems (C4I, Simulation) and the core data that would be of interest to both systems (Persistent and Non-Persistent data) during interface and/or integration activities. In two cases (Simulation Service and Non-Persistent Data) individual lines are detailed to represent individual classes, while in the others a single line reflects the entire class, with examples of information exchanges provided for consideration. The reason for the distinction between generalized categories and specific interactions is that in the 2 detailed categories cases sufficient work has been done to identify the specific classes, and it is expected that these classes are complete. An additional reason for the distinction is that in the two well-defined categories, the information exchanged is generally referred to in a similar way within the M&S and C3I communities.

To contrast this against the remaining two general categories (Persistent Data, C4I System Service), the lists presented are considered representative, and subject to variability depending on the C3I system. Further, it is felt that to completely enumerate all possible classes of information within these categories for all possible C3I systems would be of little use. Instead, an examination of requirements for each C3I system (or component) interface is needed, and consideration of the actual classes within each category (as well as its relevance to the interface design) is suggested.

Finally, the use of bi-directional arrows suggests the possibility that information flows within each class may go from C3I to simulation, or reverse. Clearly the existence of a particular class as well as whether it flows in a single direction, or both directions, is up to the requirements and design of the interface. What follows is a general description of the 4 categories. Additional information on Categories and Interaction details can be found in the source paper [2] and C4ISR/Sim TRM study group sourcebook [6].

3.1 Simulation Service Interactions

To facilitate the distribution of simulations, yet allow them to be accessible to C3I systems, interactions such as those defined within this category are necessary. These include not only information "about" the simulation (reflecting the potential that a variety of simulations are available), but also the ability to control or coordinate its execution with C3I resident activities, the transmission of possible visualization data (although not necessarily images), mechanisms for data collection from one to another, and the net results (or "simulation effects") of a simulation execution.

3.2 Non-Persistent Data

Non-Persistent Data identifies very frequent information exchange interactions (typically messages, reports, or data replication) that may occur between C3I and simulation systems (or components). It represents the major focal point for interfaces used for training and CAX. In these applications most effort for interfaces goes into generating products from simulated entities, or evaluating products from operational C3I systems. In considering the potential use of these interactions within a simulation enhanced C3I system, it is possible that data from operational sources may be duplicated in forms such as these. This would allow the use of up-to-date situation awareness data in Course of Action Analysis (COAA) or Mission Rehearsal while additional data is received by operational components. Subsequently, revised data might flow through these classes to provide last minute checks against plan for feasibility. During actual mission execution, these classes might provide valuable conduits through which data used for automated execution monitoring might occur.

3.3 Persistent Data

This category represents operational data stores native to the C3I system, and having the characteristic of infrequent changes through the course of a simulation execution. Its presence within an interface, however, is important. The ability to provide direct transfer of C3I data from suggested sources to simulation equivalents for scenario initialization purposes can provide substantial cost savings, set-up time reductions, and increased flexibility for simulation use. Significant results from this type of work are reported in papers such as Furness et al, "Realtime Initialization of Planning and Analysis Simulations Based on C4ISR System Data" [12].

3.4 C4I System Service Interactions

These are interactions that may be mandated by use of particular C3I components, or merely by virtue of being connected to a C3I system. They may not contain "data" that is exchanged between the two domains, but may be required in order to connect to the C3I system, sustain the connection, or to use a particular C3I component. In the absence of these interactions, the C3I system may fail, the interface may not be recognized as a valid C3I system (versus a commercial hardware/software platform), or be unable to communicate with a particular component. These types of interactions tend to be very C3I system/component specific, based on particular component selections, hardware/software architecture implementation, or C3I system version. Therefore, no attempt is made to enumerate them exhaustively.

Rather, two general types are identified for illustrative purposes.

4.0 Simulation System Components

The concept behind simulation component modules is that they should represent the smallest reasonable piece that might be a candidate for distribution in an architectural design. In fact, they could potentially represent individual "services" distributed and tied together with the Run Time Framework. Further, they need not be a single instance, but could be multiplied across an implementation network. This would be true if used to design client/server configurations. This serves to recognize the simulation community's work on developing "federations" of simulations. In addition, it also extends the possibility to consider that such "federations" may be available to C3I systems, which might control selection of federates used to produce simulated results via guidance provided through Simulation Metadata interactions.

The simulation system components represented in Figure 1 are generalizations that would be considered most useful for, or relevant to C3I to simulation interfaces, or potentially useful for integration between systems. It is not intended that the components identified here represents a complete set required for any simulation system. Further refinement of the C4ISR/Sim TRM may expand this area, or ultimately there may be an effort to define and establish a reference model for simulations or synthetic natural environments. To date, beyond the work done on the C4ISR/Sim TRM described as part of this (and earlier) paper and the SISO study group, there has been no effort to put forth an M&S reference model, although the author believes there may be some value in doing so. There has also been little effort to establish a common M&S implementation (e.g. M&S COE). It may be possible that such efforts will be undertaken in the future, and as a result (as described in [8]) interoperability and reuse of simulation components will be improved.

In the absence of an accepted M&S Technical Reference Model, components are included in the C4ISR/Sim TRM for the purposes of architectural design consideration. Further efforts for C4ISR/Sim TRM refinements in the simulation system components area include an examination of its completeness against the work of the European Co-operation for the Long-term In Defence (EUCLID) project [21]. A comparison against the EUCLID synthetic environment architecture, as well as components contained within the EUCLID repository may confirm the accuracy of this area of the TRM, or provide clues how it could be appropriately refined. As an alternative, additional abstractions for the simulation components may come from examination of the component architectures of such systems as OneSAF [13].

5.0 NATO MODELS & STANDARDS RELEVANCE INTRODUCTION

Part of the work of the first SIW TRM Study Group [3] was to identify 5 guiding principles for the development of a C4ISR/Sim TRM. This work concluded that the C4ISR/Sim TRM must be: Comprehensive, Traceable, Easy to Interpret, Usable, and Independent. It also presented a cursory look at several M&S and other reference models, although it did not establish or reflect the relationship (traceability) between the C4ISR/Sim TRM and these other reference models. This paper seeks to establish the relevance of the C4ISR/Sim TRM to the international NATO community by examining several NATO reference models and standards, and illustrating their relationship to the C4ISR/Sim TRM in greater detail.

The Software Engineering Institute (SEI), in their Software Technology Review [9] states: "Much confusion exists regarding the definition, applicability, and scope of the terms *reference model, architecture,* and implementation." They go on to provide definitions for these terms (Table 1) and illustrative examples of the relationship between these concepts. In keeping with the SEI definition for reference model, the C4ISR/Sim TRM is intended to be a description of all possible software components or component services and the relationships between them.

Although repeatedly considered, no effort has been made to identify specific (or abstract) components for the C3I system portion of the diagram. The rationale for this is that C3I systems are subject to their own reference models (e.g. DoD TRM, NATO TRM), architectures (e.g. JTA, NATO C3 Technical Architecture), and implementations (e.g. DoD COE, NATO COE). Underlying each of these are sustainment efforts to continually evaluate and maintain reference and usage documentation. With all of these instances, the goal (among others) is to establish, guide, measure, or improve interoperability between systems or components. As with these efforts from the C3I domain, that is a primary goal of the C4ISR/Sim TRM.

In the following analysis sections the discussion starts with showing the traceability from the C4ISR/Sim TRM to the NATO TRM (NTRM).

As an architecture is considered a subset description of a reference model for a particular domain, the NATO C3 Technical Architecture (NC3TA) is considered to be relevant in the domain of NATO C3I systems. The NC3TA provides the principal source of procedures, architectural concepts, data (standards and products), and their relationships, from which the Technical View of C3I systems or "system of systems" can be developed. From such a defined architecture individual C3I systems are composed.

Reference Model: A reference model is a description of all of the possible software components or component services (functions), and the relationships between them (how these components are put together and how they will interact).
Architecture: An architecture is a description of a subset of the reference model's component services that have been selected to meet a specific system's requirements. In other words, not all of the reference model's component services need to be included in a specific architecture. There can be many architectures derived from the same reference model. The associated standards and guidelines for each service included in the architecture form the open systems architecture and become the criteria for implementing the system.
Implementation: The implementation is a product that results from selecting, reusing, building, and integrating software components and component services according to the specified architecture. The selected, reused, and/or built components and component services must comply 100% with the associated standards and guidelines for the implementation to be considered compliant.

Table 1 - SEI Definitions

This paper seeks to argue the relevance and validity of the C4ISR/Sim TRM to the NATO community, and its potential relationship to the NC3TA. To do so, an examination of the traceability of the C4ISR/Sim TRM to various portions of the NC3TA is considered. In particular, Section 7 looks at the NATO COE (NCOE) and NCOE Component Model (NCM). Section 8 proposes a simulation server functional configuration, and Section 9 relates the C4ISR/Sim TRM to the NC3TA Interoperability Model.

6.0 NATO TECHNICAL REFERENCE MODEL (NTRM)

The NTRM [17] provides guidance to NATO developers, system architects, and individuals in using and developing systems and technical architectures. The model promotes open system design, as well as the decoupling of application and external environment from the operating platform. It is based on national defense (US DoD TRM), aerospace (NASA Space Generic Open Avionics Architecture Model), and automotive (SAE GOA model) industry efforts. The NTRM contains basic elements of the POSIX OSE Reference model, which includes three classes of entities (Application Software, Application Platform, External Environment) and two types of interfaces (Application Program, External Environment). The main purpose of the NATO TRM (NTRM) is to structure the standards listed in the NATO Common

Standards Profile (NCSP) [19].

Within the NTRM, there are 12 service areas defined, which are later used organize standards within the NCSP. In addition, there are 7 application types (Mission Area Applications and 6 Support types). In order to assess the relationship between the NTRM and C4ISR/Sim TRM, an attempt was made to map the simulation modules into the various services and applications described in the DoD TRM. The results are presented in Figure 2 and discussion of the results follows.

C4ISR/M&S TRM Module	NATO TRM relevant Application and System Service Areas
Simulation Control	User Interface Services System Management Services
Visualization	User Interface Services Graphics Services
Simulation & Models Module	Mission Area Application Engineering Support Applications Common C2 Applications Services
Simulation Engine	Mission Area Application Engineering Support Applications Common C2 Applications Services
Models	Mission Area Application Engineering Support Applications Common C2 Applications Services
Run-Time Framework	Distributed Computing Services Data Interchange Services
Databases	Database Utilities Applications Data Management Services

Figure 2 - C4ISR/Sim Mapping to NTRM

In general, each module was able to map to several NTRM services and/or applications. This reflects the fact that as a reference model, it represents a potentially unlimited number of architectural definitions and/or implementations. In several cases, the modules were successfully mapped to items in both the service and application categories. This would credit the fact that simulations, due to their power and flexibility, can be seen to provide both application capabilities to the end-user, as well as perform service level functions to the system and/or other applications.

For the C4ISR/Sim TRM Simulation Control module, the limited descriptions provided for NTRM service areas suggest that a relationship would exist between Simulation Control module and NTRM User Interface Services, or NTRM System Management Services, or both. Clearly, the simulation control module might represent the user interface to the simulation "service" and provide management capabilities for it. But depending upon the specific architecture, it may (or may not) provide a user interface, style sheets, direct access to simulation capabilities, etc. If the user interface services class was intended to represent only those on-board capabilities to construct and control user interfaces (e.g. browser, Xwindows) then the simulation control module would be squarely within the system management services area.

Similarly, the Visualization module could map to one of two different NTRM service areas, either User Interface services or Graphics services. In this case, the visualization may represent intermediate results of simulation activities. Often this would be displayed on some form of two dimensional planned view display (PVD) or possibly overlaid onto a map. The potential mapping to User Interface Services might assume the development and acceptance of a simulation domain standard PVD or Graphic Information System (GIS) as a User Interface Service. In contrast to a similar evaluation of the C4ISR/Sim TRM against the US DoD TRM [15], the Visualization module was mapped easily to the Multimedia Services category not present in the NTRM. In the US DoD TRM, the Multimedia Services category contains a descriptive reference to GIS services, while the Graphics Services (within NTRM) simply refers to "functions required for creating and manipulating pictures."

The simulation and models aggregate component might be instantiated as a Common C2 Application, or a stand-alone Mission Area Application. Further, it is also identified as a potential Engineering Support application. Unfortunately, there is an absence of descriptions for applications (including Engineering Support) within NTRM documents available, however the US DoD TRM Engineering support description refers to “decision support services”, “modeling and simulation services”, and “expert system services”, all of which are potential applications for modeling and simulation interfaces or integration.

Although simulation engine(s) or model(s) are highly unlikely to be embedded (or interfaced to) by themselves, the possibility exists. As an example, it might be desirable to embed a simulation engine, which dynamically loads models (as data parameters, executable components, etc) from some central repository. Therefore, these would have the same potential mapping as the simulation and models aggregate component. Other then this possibility, more obscure mappings could be made (e.g. Simulation Engine – Mission Area Application / Models – Data Management Services).

Finally, both Run-Time Framework and Databases could map into two categories, depending principally on the intended implementation architecture. In the case of the Run-Time Framework, perhaps the more acceptable mapping would be into Distributed Computing Services. This is due to the fact that the Distributed Interactive Simulation (DIS) protocol is already an accepted standard within the NCSP for simulation use.

It was consideration of the module mappings that reinforced that the NTRM is a very generalized model and as such cannot (or has not yet) identified all possible domain services that could be provided. Also, there is presently limited documentation to describe various entities, applications, and service areas, which makes a specific direct mapping difficult. However, in several cases (specifically Run-Time Framework and Databases) descriptions provided within NTRM documents provides a somewhat clearer definition as to the potential implementation method or purpose for the modules. Therefore, although there is value in considering a mapping to NTRM areas for the purposes of communication with systems designed and built using this model, there is still relevance to a domain specific model such as the C4I/Sim TRM, which contains descriptions that should be more clear to simulation domain practitioners. However, the most ideal solution might be the use of both reference models for a more complete description of architectural components, modules, and implementation possibilities.

7.0 NATO COMMON OPERATING ENVIRONMENT (NCOE)

The goal of the NCOE is to support the development of a distributed information system infrastructure, which promotes interoperability. The NCOE provides the minimum set of services, common standards profiles, management procedures, implementation rules, interfaces, and guidelines for product selection, as well as products to implement NATO Information Systems (NIS). The objective is to ensure their interoperability within NATO and with national systems.

The NCOE Component Model (NCM) [20] capitalizes on the NATO Technical Reference Model (NTRM), utilizing its top-down layered architecture. Individual components can be described as the individual capabilities that are transparent to the end-user. Components are in essence the distributed computing capabilities, data interchange services, management services, communications services, data management services, presentation services, security services, etc. that are inherent to the NCOE as depicted in the NCM in accordance with the NTRM. The NCM depicts the high-level functional taxonomy and overall composition of the NCOE. Within the NCM, each individual component is categorized according to the type of service provided. However, the NCM only provides a view of individual component relationships by service area only. The actual products necessary to populate each service area are selected from the NCOE 'basket of products'.

C4ISR/M&S TRM Module	NCM Service Areas	NCM Service Sub-Categories
Simulation Control	Infrastructure Services	Management Services
	Common Support Services	Enterprise Management Services
Visualization	Common Support Services	Graphical Services (or) Undefined
Simulation & Models Module	Common Support Services	Common C2 Application (or) Undefined
Simulation Engine	Common Support Services	Common C2 Applications (or) Undefined
Models		Data / Objects (or) Undefined
Run-Time Framework	Infrastructure Service	Communications Services Distributed Object Services
Databases	Infrastructure Service	Data Management Services

Figure 3 - C4ISR/Sim TRM to NCM Mapping

An analysis was done to reflect the mapping between the C4ISR/Sim TRM and the NCM. The results are provided in Figure 3. However, as described in the details below, a number of simulation specific services (or components within the C4ISR/Sim TRM) remain difficult to classify.

Visualization would seem to be implementation dependent, but could be subject to some confusion based on the underlying technology chosen for implementation. For example, simulation displays that were based on GIS packages would clearly be able to fit within the Geospatial Services category. However this category seems to be identifying those components that are end point GIS systems, rather then simulation adaptation of these products that provide “added value” (e.g. displaying simulation progress on map products). Further, several existing simulations considered during the development of the C4ISR/Sim TRM utilize “home grown” PVDs, based on X Window, OpenGL, or VRML technologies (for example). These technologies/components are suggested within the presentation/multimedia services area, and therefore it may be appropriate for these Visualization components to reside there. Yet instances exist where simulation visualization tools may be distributed independent of the simulation portion itself, so correct placement within the NCOE may be important.

Similarly, Models do not easily fit into a single component category, because of the “value added” that they provide. Potentially instantiated as a model repository, they may consist of data files or objects, with their own repository infrastructure. However, this does not necessarily qualify them for data management, or distributed object services if these categories refer to domain independent tools. Clearly at some level they represent “data” or “objects”, but specific to the M&S domain and in conjunction with (or without) the Simulation Engine they represent a potentially powerful “service” that can be invoked by other applications, or as mission applications themselves.

The Simulation & Models module and Simulation Engine component doesn’t fit easily within Common Support Services or Infrastructure Services Categories. As a default, they were associated with the Common C2 Application service, although they did not seem to be consistent with the service description

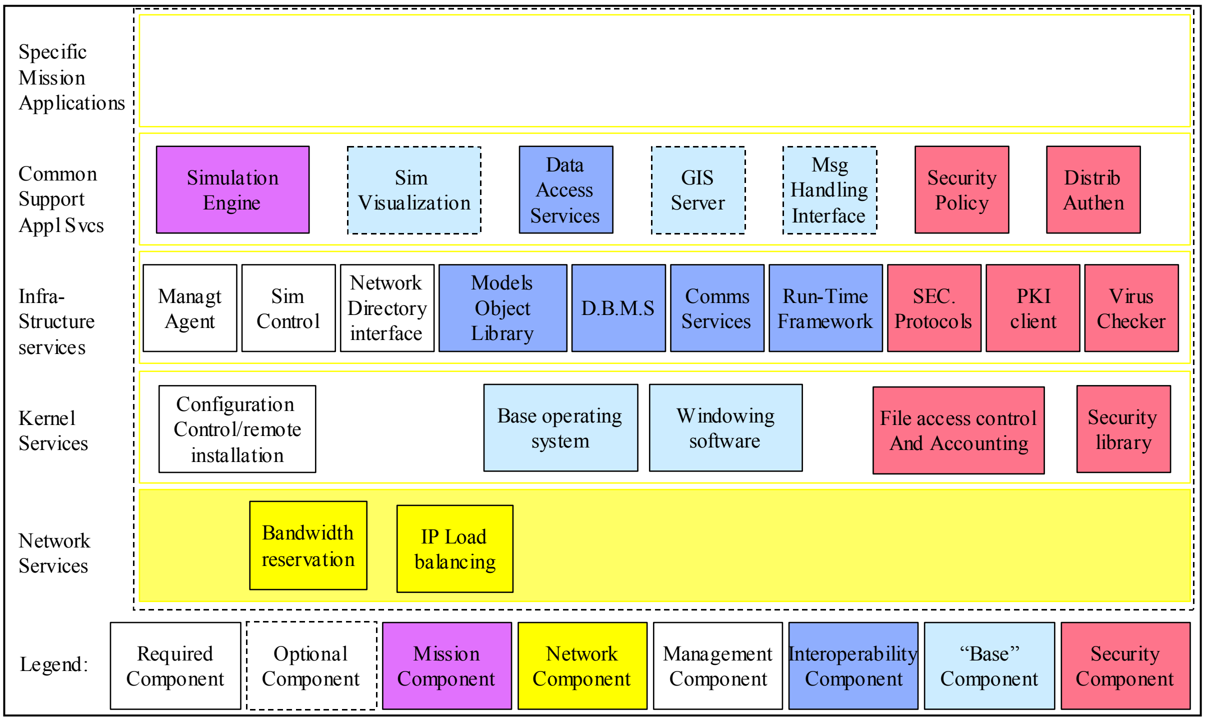

Figure 4 - Proposed Functional Components for Simulation Server

provided. Simulations, models, and simulation engine products exist in a variety of forms, not only from commercial vendors but also as by-products of nationally sponsored simulation efforts. As stated in [20] "The primary intent of the Common Support Applications is to provide the architectural framework necessary for the management, distribution and sharing of information among applications throughout a system." Further, "Infrastructure services provide a set of integrated capabilities that the applications will access to evoke NCOE services, and are necessary to move data through the network." Based on the examination of these definitions and other documentation of existing services categories, it was considered that a clear direct mapping of these simulation components was difficult.

As a result, it may be of value for the NMSG to consider development and proposal of an additional Common Support Service category. This category might be specifically oriented toward simulation-based applications or more generalized decision support services. These might not be mission applications themselves, but could provide powerful simulation based information processing or analysis capabilities to a wide audience of Mission Application developers. They could also represent the domain specific versions of various other services/applications (e.g. visualization, model repositories) that could be shared among simulation developers, or instantiated onto C3I systems.

As an example category, "Decision Support Services" might apply to a category of service level applications that provide intermediate processing of data/information from lower level (Infrastructure Service) components or data sources. Yet these "Decision Support Service" components may be general enough that they can be reused based on a common input format/standard and appropriate APIs. To extend the recommendation, it could be considered a "base" component, similar to "Document Management", "Message Handling", "Office Automation", or "Geospatial Services".

8.0 REFERENCE MODELS FOR FUNCTIONAL CONFIGURATIONS

Volume 2 of the NC3TA [17] introduces Functional Configurations (FC), which are composed of application and foundation services and interface functionally with one another. A full overview of FCs is provided in Annex B, and shows 9 FC examples that constitute an initial, although not all-inclusive list of FCs that will be validated and/or updated in future versions of the NC3TA. An examination of the existing FCs resulted in none that appeared fully appropriate for a simulation server configuration. As a further evaluation of the utility of the C4ISR/Sim TRM, a proposed FC configuration was developed and appears as Figure 4.

The motivation of a simulation server FC is the same as other FCs. It can be used to reduce architectural complexity, promote and encourage the judicious use of NCOE components, and improve interoperability. These and other reasons are consistent with recommendations made to SISO for the establishment of an M&S COE in a recent paper entitled: “Interoperability and Reuse through a Modeling and Simulation Common Operating Environment” [14]. Further motivation can be seen through the existence of other “server system” FCs, including Database Server, Web Portal/Application Server, Documentation Management Server, Messaging and Communications Server.

9.0 NC3TA INTEROPERABILITY MODELS

In order to classify NC3I Interoperability, the ISC has included in their NATO Policy for C3 Interoperability (PO(2000)39), 4 degrees of interoperability. These degrees are broken down into sub-degrees and are intended to classify how structuring and interpretation of data can enhance operational effectiveness. The sub-degrees are then be mapped to groups of standards to be referred to during the selection process.

To show the relationship between the C4ISR/Sim TRM and the applicable standards within the NC3TA, a mapping was done from the various interaction classes within the model to the interoperability sub-degrees within the NC3TA. This mapping is represented below, with specific point discussions to follow. The utility of such a mapping is that it provides a guide to interface efforts as to which categories of standards need to be considered during their efforts. It can also serve as a roadmap for NMSG standards consideration/development effort to focus on those categories where relevant standards are missing.

TRM Major Category	Interaction Class	NATO ID	Sub-Degree Name	Notes:
Simulation Service Interactions	Simulation Metadata	2.B	Enhanced Document Exchange	Assume hypertext
	Execution Control	1.C	Basic Informal Message Exchange	DIS, ALSP, RTI
	Visualization	2.B	Enhanced Document Exchange	Moving Image/Graphical Image
		2.D	Map Overlays / Graphics Exchange	GIS Geographic maps, overlays, military symbology
	Data Collection			Various forms: Potential from set of any/all Non-Persistent & Persistent Items
	Simulation Effects			Various forms: hypertext, graphical, data file
Non-Persistent Data	Orders	3.A	Formal Message Exchange	

TRM Major Category	Interaction Class	NATO ID	Sub-Degree Name	Notes:
	Reports	3.A	Formal Message Exchange	
	Imagery	2.B	Enhanced Document Exchange	Graphical/still image data, moving image, audio/visual data exchange
	Tracks	3.B	Common Data Exchange	Services for DBMS
		3.F	Real Time Data Exchange	Tactical data links
	Unit Data	3.B	Common Data Exchange	Database Replication
Persistent Data		2.A	Enhanced Informal Message Exchange	Message Logs
		2.D	Map/Overlay Graphics Exchange	Terrain Specification
		2.H	Data Object Exchange	Message Logs
		3.B	Common Data Exchange	Database
C4ISR Service Interactions		2.C	Network Management	
		3.C	System Management	
		3.D	Secure System Management	
		3.E	Security Management	

Figure 5 - C4ISR/Sim TRM Mapping to NATO Interoperability Degrees

The Non-Persistent data interactions mapped easily to the categories that would be expected for components and/or interactions among C3I systems. In cases where mappings indicated above were incorrect, users of the C4ISR/Sim TRM would be expected to utilize the interoperability profile for the specific machine (or type of machine) that was subject to interface or integration.

As indicated in the C4ISR/Sim TRM source paper [2], the items within the Persistent Data and C4ISR System Service categories are considered representative and subject to variability depending on the C4I system or proponent service. Therefore, the mappings in these two categories are also generally suggestive rather then attempting to make a single correspondence. In these two cases, no specific details for interactions are made, but general selections for sub-degrees represent common categories for items contained within the Notes column.

Identifying and categorizing the various simulation service interactions into sub-degrees was somewhat easier, yet subject to the same level of variability. The most likely form for simulation meta-data would seem to hypertext or XML formatted messages. For the purposes of simulation execution control, the example of legacy system usage of specific protocols, such as Distributed Interactive Protocol (DIS), Aggregate Level Simulation Protocol (ALSP), as well as current use of the High Level Architecture (HLA) Run Time Infrastructure (RTI) were considered. Of these, only DIS is referred to in the NC3TA standards document [18], although NATO acceptance of the HLA has occurred.

Data collection can take the form of discovery (and transfer) of numerous items from the C4ISR system, and potentially from the simulation. As a result, the sub-degrees that would be applicable would be as wide as the set of items for each system individually. Research in the area of simulation effects is still relatively new, and therefore difficult to classify the form that it might take. It could be a representation of a hypertext document (2.B), or perhaps a rendering on a Graphical/GIS image (2.D). Ultimately it may represent the influence of a particular datafile or operational database that is returned to the C3I system.

10.0 SUMMARY

This paper has provided an overview of the evolving C4ISR/Sim TRM, and examined the traceability of it to the various component reference models and standards of the NC3TA. The importance of the traceability to aid on-going efforts to establish C3I to simulation interfaces, the use of COE components within those interfaces, and the desire to migrate simulation based components and applications onto C3I systems. In the absence of an accepted (or mandated) simulation TRM, the simulation community has been free to model, architect, and implement what they choose. However, if those components are placed directly onto a C3I system, they would be subject to the models, architecture, COE, and standards as defined within the NC3TA.

As the analysis has shown in many cases, obvious relationships exist between components (and interactions) of the C4ISR/Sim TRM (and by extension the simulation domain) and the NC3TA. In other cases, the relationship is more obscure, principally due to the “generic” nature of the NC3TA. However, it has been pointed out where simulation domain specific contributions can be made within the framework of the NC3TA, that would help to make it more relevant to the simulation community. Through efforts such as this, it is suggested that the task to establish interfaces, and integrate components would be made easier, and the results more interoperable.

The following are the summary of the specific recommendations to the NMSG for this effort:

- Development and recommendation of simulation based Common Support Service category, for inclusion within the NCM.
- Development and formalization of Simulation based Functional Configurations, Technical Configurations, and Internal Interoperability Profiles.
- Identification of additional simulation based standards (e.g. HLA, SEDRIS) for inclusion in NCSP.
- Examination of C4ISR/Sim TRM to ensure that lexicon and representations are sufficiently generalized and consistent with NATO standards.
- Further examination of validity of C4ISR/Sim TRM, and consideration of Annexed inclusion within the NC3TA.

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My affiliation with The MITRE Corporation is provided for identification purposes only, and is not intended to convey or imply MITRE's concurrence with, or support for, the positions, opinions or

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ALLIED COMMAND TRANSFORMATION ROLE IN MODELLING AND SIMULATION

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1. The purpose of this presentation is to give you an update on the Transformation process that has taken place within NATO and in particular, the Supreme Allied Commander Transformation (SACT) HQ. How we at SACT see ourselves interfacing with R&T organizations and agencies and more specifically, how modeling and simulation will play an important role in this process.

2. To effect a cohesive, collaborative and focused transformation, our leaders decided at the Prague Summit in November 2002 designated a command to be the driver for change within NATO. To function as the focal point for managing the range of issues affected by transformation: interoperability, jointness, experimentation, education, and conceptual and doctrinal development. In order to ensure that we find new ways to sustain and improve our ability to fight as an interoperable allied team, Allied Command Transformation was established with responsibility for managing differences in capabilities as our militaries innovate and technology provides them new tools.

3. Allied Command Transformation has been assigned the mission of leading the transformation of NATO forces. It will be accountable for producing forces that bridge the difference in alliance capabilities and capitalize on the competitive advantages of national contributions. Supreme Allied Commander Atlantic transitioned to become the Transformation Strategic Commander for NATO on June 19 2003. SACEUR became the sole Operational Strategic Command through a realignment of functions/ tasks along an operational/functional line. The NATO Transformation process is now established allowing one command to be the driver for change, to provide the focused effort necessary to advance new technology, policy and doctrine within the Alliance. This one command will have the ability to concentrate on Transformation with the other strategic commander focusing on operations. Allied Command Transformation will be the advocate for new doctrine, concepts, and innovations within the Alliance.

4. To bring about the Realignment of the two strategic commanders to realize on operational and one transformational command, the staffs of the two strategic command headquarters sat down to assess the tasks assigned to each. The staffs identified operational tasks to be transferred to SACEUR as the operational commander and tasks to be transferred to SACLANT in order to identify all tasks and insure there would be no decrease in the output of the two strategic commands as they transitioned to their new missions.
It is with this realignment of tasks and we realize the mission and structure of the two new strategic commands. Here at HQ SACT we commenced operating as the transformational command on 19 June 2003 with the transfer of command authority of all operational assets to SACEUR, the deactivation of SACLANT and the activation of the Supreme Allied Commander Transformation. Over the course of the next several months the staffs will commence transfer of tasks, pending placement of budget and manpower at the applicable strategic command.

5. On 19 June 2003 with the activation of the Supreme Allied Commander Transformation, we were once again linked the US Joint Forces Command when their commander was once again dual hatted as the Strategic Commander for NATO here in Norfolk. The post for our commander is no longer gapped or filled in an interim capacity by the Deputy, but reflects the dual hatting with US Joint Forces Command. Our previous area of responsibility was the North Atlantic and we specialized in Maritime issues. As a result we have been manned by Navy Flag Officers. In an effort to become the Transformation command for NATO we are working with nations to fill posts with officers of other services. As you can see here we are making great strides. Our Joint Education and Training and C41 sub-divisions are being headed by Air Force General Officers, and we have Army General officers holding the positions at the Joint Warfare Center / Strategic, Concepts, Policy and Integration / and Defense Planning.

6. We have organized ourselves into two major departments – Transformation and Transformation Support under which our divisions and sub-divisions are aligned. We are a totally new command – in mission and in structure and there is no basis under which the two can be compared. When our Outline Peacetime Establishment for the headquarters is agreed by nations we will have approx 550 personnel here on staff at the Headquarters. Given the physical distance between HQ SACT and NATO HQ in Brussels, the position of the SACT Representative in Europe, or SACTREPEUR, cannot be understated. He and his staff are physically located at NATO Headquarters and are a vital link in providing SACT's advice and perspectives to the political and military leadership of the Alliance on a daily basis.

7. The Sub-divisions are Implementation and Capabilities. We'll first look at the Capabilities functions to give you a better understanding exactly what the term capabilities means and what some of our outputs will be. Liaison will be established with the US Joint Forces Command in Norfolk, Virginia for transformational efforts and strong ties will be established with the staff at the Allied Command Operations. To fully execute our tasks of providing education and training for allied personnel we will establish close working ties with established NATO schools and for experimentation purposes we will work closely with NC3A, NURC, the RTO, and national Centres of Excellence.

8. We have made a lot of progress in a very short space of time, but there is a lot more to do yet before we consider ourselves fully transformed. This Status/timeline - presented in the Implementation Directive provided by the International Military Staff - is ambitious we know, but it is the goal that we are working hard to achieve.

9. We think we are still ahead of the work - but this represents a very significant amount of work still to be accomplished in the near future.

Deliver the Bi-SC DIP	30 Sep 03
Obtain MC agreement on Flags to Post	15 Mar 04
Final PE - MC agreement	30 Sep 04
Begin manning of new PE posts by Nations from	1 Nov 04
Declare NCS IOC by	30 Jun 05
Declare NCS FOC by	30 Jun 06

10. Transformation in the context of the Alliance is defined as a continuous process of development and integration of innovative concepts, doctrine and equipment in order to improve the effectiveness and interoperability of war-fighting forces. During this process the use of modeling and simulation provides us the capability to build and test our vision, concepts, doctrine and equipment this way we can create an environment in which the Alliance is pro-active rather

than reactive, and where capability requirements are anticipated rather than developed following emergence of new security threats. This continuous process starts by identifying future requirements for NATO forces and comparing them with current force capabilities and near term improvements to establish the extent of any shortfalls. Potential solutions will be identified in the form of concepts that can be developed and experimented within a collaborative manner with Modelling and Simulation. This concept work could involve the development of prototype equipment, and/or doctrine, training, infrastructure improvement. To support this, Strategic level operational analyses will be conducted to identify the type and scale of capabilities and interoperability that the Alliance will require. In parallel, ACT will acquire an in depth knowledge of both the Alliance's current capabilities and intended improvements to national capabilities in order to clearly establish where the Alliance needs to concentrate its future efforts. These will inform the Defence Planning Process and will result in a Strategic Transformation Vision that clearly identifies and prioritizes the Long Term Capability Requirements of the Alliance. As you can see modelling and simulation will be used every step of the transformation process.

11. The following activities of the transformation process should be supported with modelling and simulation tools:

Analysis of Capability Requirements
Concept Exploration and Development
Concept Experimentation
Operational Training and Exercises

12. Starting first with the analysis that is conducted to identify NATO's capability requirements. This work involves the assessment of NATO's 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. Modelling and simulation has also an important role in the experimentation process. The simulation models allow examination of the real-world concepts in a simulated environment. The live domain is a representation of military operations using live forces. The virtual domain is a replication of actual war fighting equipment, systems and includes computer-generated battlefields in simulators. The constructive domain includes simulations that represent actions of people and systems in the simulation. Experiments could benefit from one or combination of these M&S domains. 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 should 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 modelling cost, as they

should be multi-resolution to optimize 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.

NATO Annual Modelling and Simulation Conference
"C3I and Modelling and Simulation Interoperability"

Closing Remarks

Mr Graham G. BURROWS, Head, NMSCO
Conference Committee Chairman
RTA - BP 25
92201 Neuilly sur Seine, France

Mr Burrows provided the following closing remarks:

Summary of initial Key Points emerging from Conference:

- Modelling and Simulation has a pivotal role in every phase of the NATO Transformation Conference.
-
- There are many promising approaches, but we do not yet have good interoperability between M&S and C3I systems.
-
- Knowledge of C3I systems architectures and dat/object models should be mandatory. There is still much education to be done in C3I and M&S.
-
- Commercially supported open standards are increasingly being used as add-ons to specific M&S standards, in particular web services and XML. But, to align these approaches, overarching methods are needed.

He thanked:
- The National Hosts (Turkey) for hosting the Conference and for providing excellent support and facilities.

- The participants for attending, providing excellent Papers and positive, stimulating questions and comments.

- The Interpreters – It had been a real challenge keeping up with the many different accents and speeds of delivery, but as usual they rose to the challenge.

He announced:
- The next NATO M&S Conference will be held in Germany, on 7 and 8 October 2004 with the Theme – M&S to Address NATO's New and Existing Military Requirements.

He finally wished participants a safe and enjoyable journey home.

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CAX (Computer Assisted Exercise)
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Communication protocols
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Data modelling
Decision making
Decision support systems
Distributed systems
Interoperability
M&S (Modelling and Simulation)
MDA (Model Driven Architecture)
Military planning
Military training
NATO C3 technical architecture
NATO M&S Master Plan
Support of operations
Technical reference model
UML (Unified Modelling Language)
Web services

14. Abstract

Among various military applications of M&S within the Alliance, Operational Support and Training are identified as high priority areas. To support these areas, interoperability of legacy and future Command, Control, Communications and Intelligence (C3I) and Modelling & Simulation (M&S) applications is required. The NATO Modelling and Simulation Group (NMSG) Conference (MSG-022) "C3I and M&S Interoperability" was conducted in Antalya, Turkey from 9 to 10 October 2003. All sessions of the Conference were unclassified. The conference focused on:

- Lessons learned from past experience in linking C3I and M&S,
- Current Joint use of C3I and M&S in Computer Assisted Exercises (CAX),
- Interoperability and data standards,
- Future projects.

Two keynote speeches, one capstone document, and 19 papers were presented covering NATO efforts as well as efforts of the nations. Furthermore, the results of organizations dealing with the issues of C3I and M&S interoperability were presented as well, in particular the work of Simulation Interoperability Standards Organization (SISO) and the European Co-Operation for the Long-term in Defence (EUCLID). The conference presented state-of-the-art solutions, helped to define future Research & Development domains, and gave an overview of the contribution capability of the participating nations and organizations.

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