Decision Support Systems – An Overview of Ongoing German Efforts

Major Dietmar Kunde
Heeresamt V (3) (German Army Office)
Bruehler Str. 300
D-50968 Cologne, Germany
+49-221-9371 3214
DietmarKunde@bwb.org

Dr. Andreas Tolk
Industrieanlagen-Betriebsgesellschaft mbH (IABG)
Einsteinstr. 20
D-85521 Ottobrunn, Germany
+49-89-6088 2381
tolk@iabg.de

Abstract

Simulation systems currently in use to train the military personnel in the German Army in computer assisted exercises (CAX) have originally been designed to cover the scenarios of the cold war. Although recently effort has been made to model successfully scenarios like of the task force detached in former Yugoslavia using this systems, there are still other challenges to be solved in order to meet high-end standards of interoperability, modular architecture and VV&A in order to meet the requirements of time, quality and effort. These topics have to be sufficiently covered by simulation systems when being used for decision support (DS). Together with additional military requirements they are motivating respective ongoing efforts in German Research and Development Studies.

Therefore, this paper gives an overview of the military requirements for systems being eligible for Decision Support, points out some of the technical prerequisites found in this context and depicts some of the latest activities to gain such systems, e.g.,

- *the C2 Analysis model FIT demonstrates the ability to optimize command and control structures as well as communication links depending on the actual/simulated necessities;*
- *the Study Decision Support Tools II yield results for data mediation, demonstrated the advantages of a common data model and combined several COTS-products;*
- *the German artillery extends their DS ability by developing automated forces in order to support the planning process on the division level.*

In summary, this paper is dealing with the conceptual requirements for decision support systems to military operations, technical prerequisites and examples of completed and currently conducted studies in this context.

1 Introduction

Until recently, the main application domains of combat simulation systems (constructive simulation) have been analyses and training and exercises (computer assisted exercises – CAX). Simulation based acquisition (SBA) is another application domain of high interests. However, from the theoretical point of view all three areas are quite well known as typical domains of simulation systems and many applications and experiences are available.

Compared to this, the idea of "bringing modeling and simulation to war" is relatively new. The domain of support to operations or decision support systems is a new domain with new requirements. There still is not a real consensus how to meet respective requirements, which architectures to choose, whether it is possible to use the same family of simulation systems for decision support (DS) as well as for CAX, etc. Looking, e.g., at the architectural issues, solutions are ranging from integrated solutions of modular and configurable systems (see [Tolk, 2000b]) to loose coupling of systems with a minimum of mutual influence (see [Menzler et al., 2001]).

To give an overview on what is going on in Germany, this paper is dealing with the conceptual requirements for Decision Support to military operations as well as with examples of completed and currently conducted studies in this context. It is not the purpose to recommend them as general solutions but is offering our lessons learned as open contributions to the community.

2 Military Requirements for Decision Support

DSS are considered eligible in all phases of the C2-process, in all branches of the army and all levels of command depending on the type of military operation, the time available for decisions, the time needed for getting results with DSS and the availability of adequate data. Therefore there won't exist a unique DSS that covers all problems to be solved but a set of DSS optimized for the special demands and place being needed. It is unquestioned DSS can support the military commander and his staff; they do not supervise the decisions and never ever replace the human decision-maker.

DSS requires the modeling of the different types of operations quickly and sufficiently realistic with its relevant parameters and influencing factors, own and collaborate forces as well as the neutral or hostile forces. The Information demand to sometimes unprepared problems requires highly flexible systems, a variety of available methods and a common architecture including the C4IS in order to conduct the operation responsibly. High-quality results have to be achieved with few efforts in short time. Therefore we shouldn't concentrate only on simulation systems in order to avoid neglecting analytical methods that solve problems sometimes faster and better. However, simulation systems are just for the COAA a very helpful tool. For further issues see [Tolk and Kunde, 2000].

Reducing the effort to gain results is a major issue in using simulation systems to DS. The emerging technology of using command agents may and only may help solving this problem. Especially, the modeling of peace support operations with its problems of intangibles, co-evolving landscapes and non-linearity in human behavior require new techniques. The traditional CGF are still valuable and their development, especially the leveraging, has to be pursued constantly.[1]

The following section is dealing with the requirements to implement CGF or command agents in simulation systems to be used as decision support systems.

As already pointed out in [Tolk and Kunde, 2000], there are four technical core requirements to be met by simulation systems when supposed to be used for decision support

- All processes relevant to the decision have to be modeled adequately within the supporting system to take their influence into account properly.
- The data needed by the model has to be extracted from the C4ISR sources, i.e., the data models of the simulation system and the delivering C4ISR sources have to be aligned.[2]

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[1] It should be pointed out that computer generated forces in general – and especially command agents – do not necessarily have to be implemented as software agents. Although Agent Based Modeling (ABM) is an upcoming methodology in software development, more traditional techniques may lead to the same results. Germany is also doing R&D work on ABM. However, the works referred in this paper do not use ABM methodology explicitly.

[2] Although this is not the main topic of the paper, the authors like to stress the importance of this point. The problem is depicted very clearly, among other papers, in [Hieb and Blalock, 1999] and [Wartik et al., 2001].

- Methodologies, procedures, and algorithms to deal with the uncertain, unsharp, inconsistent, and contradictive data of the C4ISR sources transforming them to create an initial state for the supporting simulation system are needed.
- Command agents are needed to model adequate and situation dependent behavior of the simulated forces in the needed detail.

The last point is the motivation for the work being described in this section. Therefore, it will be explained in a little bit more detail. When using simulation systems for support to operations, two aspects connected to command agents make them a hard requirement:

- Command agents are needed to model the behavior of simulated elements in an intelligent and situation adequate way.
- Command agents reduce the amount of input effort tremendously and make high detailed simulation systems usable for short time analyses.

The first bullet seems to be obvious. It is necessary for all elements to behave intelligently within the simulation. If the opponent forces do not change their tactics when being confronted with a new own one, the result of the simulation is at least questionable. If the neighbors do not react in a sufficient manner in the case of a flank attack, the result of the simulation will not match reality in a way usable for decision support. Therefore, command agents are essential for simulation systems for support for operations concerning quality.

The second bullet addresses a more a practical problem. When relatively high detailed models are needed to fulfil the requirements of the first class, that leads to a lot of simulated elements for all of which orders are needed. If no command agents or similar techniques are used, at brigade level, approximately 800 orders have to be created in a high detailed model. Taking into account that not only the orders for the brigade are needed, but also for the neighbors and – last but not least – the orders for the enemy increases this number by the factor of four to six resulting in a number of 3,000 to 5,000 orders to be created for just one alternative. It can be imagined that this effort is much too much for a brigadier in his headquarters. Not having a supporting tool like CGF for harmonized order generation would make such a simulation for decision support on the battlefield unusable.

Therefore, only if adequate command agents are used within the simulation, the simulation system can be used for support to operations.

3 Examples for DSS

3.1 The German Command and Control Simulation System FIT

This section will present a German solution. As far as the authors do know this approach in its state of maturity is unique and is the first implementation of a modular, configurable, and model independent simulation system (or better simulation module or component) for command and control modeling and evaluation worldwide.

In order to meet the stated requirements, the simulation system FIT (*"**F**ührung und **I**nformations-**T**echnologie"* = Command and Control and Information Technology) was defined and implemented. The main core design elements have already been presented during a NATO Studies, Analysis, and Simulation (SAS) symposium in January 1999 as well as in [Tolk, 1999]. Additionally, the system as implemented is described in more detail in [Eberhard, 2000].

FIT is going to be implemented in gradual phases. In the first phase, the core functionality has been implemented and can be accessed over proprietary but well documented interfaces. In the just started second phases, the interfaces are adapted to the HLA, i.e., the FIT module is becoming HLA compliant federate to be used within any appropriate HLA federation. In the following phases, the results of the reference data modeling using ATCCIS/LC2IEDM as well as improved functionality and additional features will be implemented to realize the vision proposed in [Tolk, 1999].

Within the rest of this section, the actual functionality of the system will be described. The transfer of the interfaces to HLA compliance as well as the introduction of standardized reference models for information exchange is just a matter of schema transformation and schema integration as defined in [Tolk, 2001], i.e., they are more or less technical details to make the functionality accessible for various other federates.

Although the primarily intentioned application domain of FIT is the analyses of command, control, and communication, it is of tremendous value for decision support also. As already pointed out in [Tolk and Kunde, 2000], it is a necessary requirement for simulation systems when being used for decision support that all simulated entities are behaving in a situation adequate manner, i.e., respective command agents have to control them depending on existing orders, situation perception, own available resources, the intent of the superior command, actions of the enemy forces, etc. It will be shown that FIT can be used as a framework to model and implement functionality meeting this requirement.

The main requirement for the modeling of the command and control process was the possibility to model different types of headquarters and command posts. Thus, scalability and configurability were essential to be built into the systems architecture. Furthermore, different types of tasks, personnel and material resources, support by C4I systems, inner and outer organization structures were planned to be the topic of evaluation as well as adequate representations of reality for decision support systems.
As a result of these requirements, and object oriented, modular, and scalable approach was chosen for the design and implementation of the command and control process. The model itself is workflow oriented, i.e., the tasks to be conducted by the headquarter are broken down into workflow structures first. The next step is to assign resources (personnel and material) and resource dependent time constraints to each sub-process. Next follows the definition of the overall resources within the headquarter to be modeled as well as a standard derivation for this resources and the possibilities to be used elsewhere then modeled by the standard. This resource constraint workflow model is the backbone of the modeling process. Every time an event occurs, the respective workflow is invoked. Dependent on the actual available resources, the necessary sub-tasks are fulfilled. If the needed resources are not available, other process may be stopped to get their resources, depending on the priorities of these tasks. If no tasks of lesser priority are using the needed resources, the process has to wait until another higher prioritized task ends. Figure 1 shows the resulting object structure.

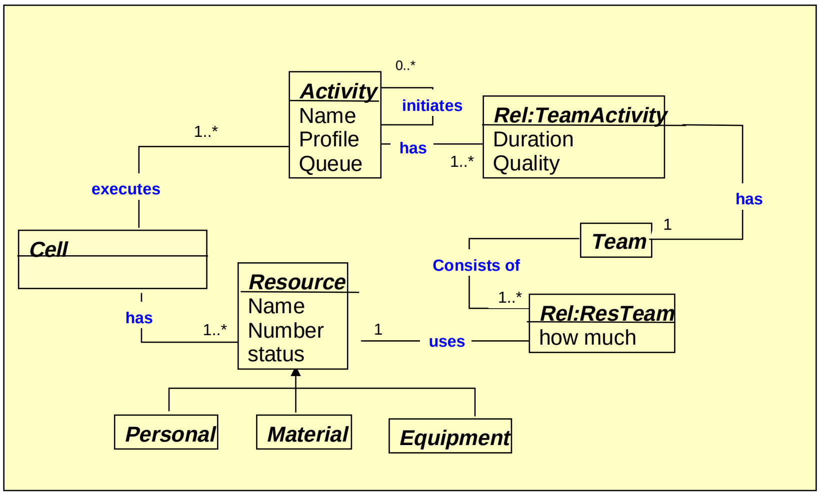

Figure 1: Description of the object structure

The following example is designed to make the reader understand the structure of the model a little bit better. Every time a new message enters the command post it has to be evaluated, whether this is a significant change of the situation requiring a new decision process. Therefore, several sub-tasks have to be done: the message has to be registered; it has to be checked, whether the reported object is an own one or not; depending on the result, the message has to be passed to the S2 or S3 section; the perception of the situation has to be updated, etc. Some of the sub-tasks may be sub-tasked again, e.g., evaluating whether the reported object is already in the map; doing consistency checks; redrawing the situational display; etc. For every task, a team of special soldiers is needed. As long as they are free, they can perform the task, however, if they are doing something else, it is a matter of priority whether to register the new messages first or to assist the S3 in the perception process.

The command and control model has an own database support, so that it is possible to save the different workflow, resources, etc. This allows the reusable definition of special command post, e.g., a standard German brigade headquarter with and without support of the new generation of C4I systems, etc.

To summarize, this model enables the user to design command posts on all military levels in a very flexible way. It is also possible to model human behavior as well as group or organizational behavior implicitly as well as explicitly (team dependent time or efficiency constraints). However, it should be pointed out that the model itself is just a framework delivering results only as good as the respective user's input. It is therefore recommended not only to verify the model, but also the respective data to enable the great potential use of this modeling framework.

All simulated entities respective command agents, command posts, and headquarters have to share information. Within the FIT model, it is possible to model the interior as well as the exterior communication connections and means explicitly. The technical parameters of the communication means as well as environmental influences are taken into account. The communication model itself is again open, modular, and configurable.

In the moment, different radio types, satellite communications, ISDN networks, and LAN are modeled.[3] The model takes the reports, messages, situation perceptions, etc. to be communicated between the entities and evaluate time and quality of the transmission. This allows the modeling of electronic warfare as well as information operations.

As far as the evaluation of similar efforts showed, the German FIT model is unique in its complexity as well as offering functionality. Being on the way to become a full functional HLA federate, it can be adapted to every simulation system to be used as a command agent for analyses of command and control, as a helpful tool in computer assisted exercises for the OPFOR as well as for neighbored troops, and – last but not least – as command agents in simulation systems to be used as decision support systems.

3.2 Decision Support on Brigade and Division Level

Another aspect of decision support has been covered by two research and development activities building the topic of this section. Within the study "Decision Support Tools" for the first time in Germany an operational command and control systems was coupled with a simulation system being used mainly for computer assisted exercises (CAX) to give decision support for the military leader within the headquarter.

Based on the results of this study, an improved technical solution for the coupling has been implemented within the study "Command and Control to Simulation Proxy Solution (C2Sim-Proxy)" using data replication as well as the runtime infrastructure (RTI) to do the coupling.

In this section, the objectives, constraints, and main findings and results of these studies will be presented to give a first impression without going too much into technical details. However, additional information and papers are available.

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[3] ISDN = Integrated Service Digital Network; LAN = Local Area Network

3.2.1 The German R&D Study on Decision Support Tools

During the past years, starting already in 1993, the R&D study "Decision Support Tools" (divided in two main phases: Part I and II) has been conducted on behalf of the German MoD. The study researches and demonstrates prototypically how decision support systems can be integrated in the command and control process to support the military commander and his staff.

In Phase I (1993 – 1997) the objective was to find out whether and how means of applied operations research can support the military decision process within an headquarter on brigade or division level. The main focus therefore lay on the support of alternative courses of action (ACOA) development and analysis. To this end, add-ons to an existing operational command and control information system had to be evaluated, chosen, and coupled with the respective CIS. As the CIS, the German Army Combat Information System HEROS 2/1 was chosen. For the integration, a simple message flow using the NATO standard messages ADatP-3 “Own Situation Report” and “Enemy Situation Report” was chosen. For decision support, the following systems were used as add-ons to the CIS:

- The Expert System for Data Aggregation and Data Fusion HADES, developed by the German FGAN institute, analyzed the enemy situation reports (sitreps) to do aggregation and fusion resulting in an improved situation perception (removing double messages, doing consistency checks, deriving new information, e.g., borders, attack routes, etc.).
- Based on the improved enemy situation perception and the own sitreps, the Artillery Expert System ARTEX, developed by the German firm ESG, evaluated areas of special interest, e.g., main point of attack, places of the enemy reserve, etc. It also produced a priority list of targets that could be used to find out what the main objectives for alternative courses of action should be as well as what means could be used (e.g., artillery versus helicopters).
- For the evaluation of the ACOA, the simulation system KORA/OA, developed by the German firm IABG for computer assisted exercises on division level, was fed with the improved enemy situation as well as the own situation creating the initial state for the simulation. Using the priority list of ARTEX, the ACOA could be simulated and the simulation runs could be evaluated using the standards tools of the KORA simulation and evaluation environment.

Using this message based decision support environment, experiments with the German Army were conducted to proof that such technical support really improves the military decision process by reducing the time needed to make a decision as well as by improving the quality of the decision by automatic consistency checks, constraint evaluation, etc. Figure 2 shows the system architecture of phase I with the three add-on systems and the message based information flow.

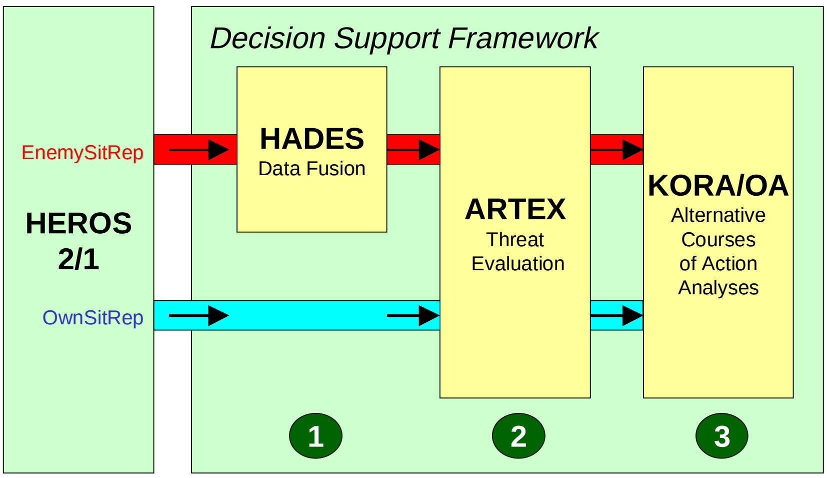

Figure 2: System Architecture

The experiments with the military user as well as additional evaluations of respective CAX experiments led to new requirements concerning the way of using the decision support systems. In phase I, the way to use the systems was hard wired. You had to use HADES first, then ARTEX, and last KORA. However, the user asked for a more flexible use already in a very early state of the experiments. E.g., he wanted to use the ARTEX tool for evaluation of the development of the situation simulated by KORA. In other words, the coupling of the add-ons should not limit the use of the tools in an inadequate manner.

Consequently, at the end of phase I a new, more flexible system architecture was defined that enables the integration of different means of applied operations research in a sort of "plug and play" philosophy. Figure 3 shows this open, modular, and configurable target architecture.

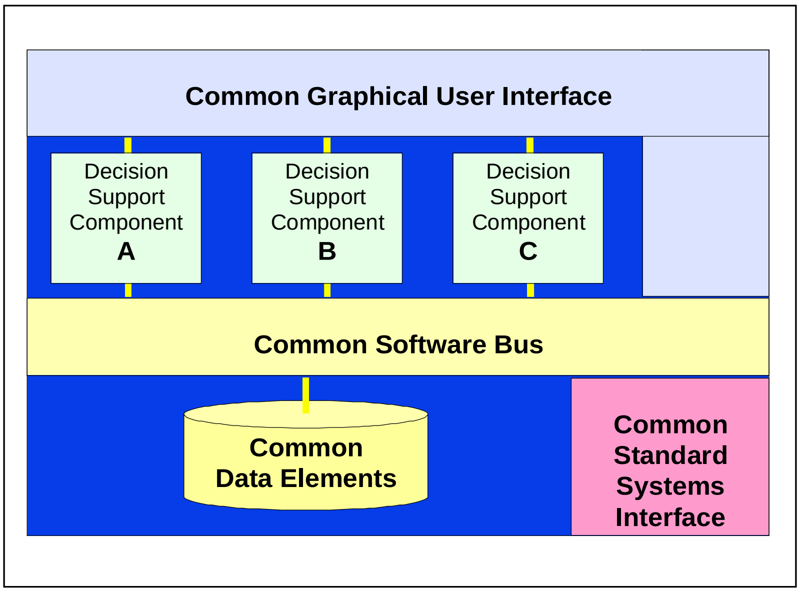

Figure 3: Target Architecture

The kernel idea is to use a common data source comprising all data needed by the respective means of operations research (simulation modules, expert systems, optimization programs, data bases with additional information, etc.) that is initialized by the underlying CIS. A software bus with additional data transformation layers brings the data needed in the format needed to the module. A common graphical user interface enables the user to access all decision support modules over the same environment also used by the CIS. With this vision, phase I ended.

The second phase of the study was initiated in 1997. From 1998 to 2000, phase II was conducted with the objective to define in implement a technical integration platform realizing the vision defined at the end of phase I. Taking into account the results on several studies on data management and alignment, as well as the new simulation interoperability architecture proposed by the NATO Modeling and Simulation Master Plan [NATO, 1998] – the High Level Architecture HLA –, the following components were used to realize a prototype of a general information integration platform for defense applications:

- The runtime infrastructure (RTI) of the HLA should be used as the communication backbone, i.e., the software bus was the RTI 1.3NG distributed by DMSO.
- To facilitate the access to the complex RTI functionality, an object-oriented shell developed by the German WTD81 in behalf of the Federal Procurement Agency was used, the German Federal Armed Forces' interface to the RTI: ψ-SA (PSISA: **P**roposed **S**tandard **I**nterface for **S**imulation **A**pplications) [Menzler et al., 2000]

- The information exchange requests of the models were satisfied by the exchange of standardized data elements (SDE) of the data model ATCCIS/LC2IEDM[4]. The mapping of the legacy information objects of the models to the SDEs and vice versa is done by a standard software component, the Data Mediation Functionality (DMF) module.

To make the whole system work, for every module an additional federation layer was needed to connect the legacy import/export interface of the model with the DMF module. Furthermore, the data model ATCCIS/LC2IEDM had to be implemented to be used on the RTI, i.e., an HLA-OMT version of ATCCIS/LC2IEDM was needed. As ATCCIS/LC2IEDM is an emerging NATO standard (ADatP-32), the resulting Federation Object Model (FOM) was called the ATCCIS Reference FOM (ARFOM). For the control of the overall process, a CORBA (Common Object Request Broker Architecture) based control component with access to all layers and modules was implemented too. The resulting architecture of the prototype is depicted in figure 4.

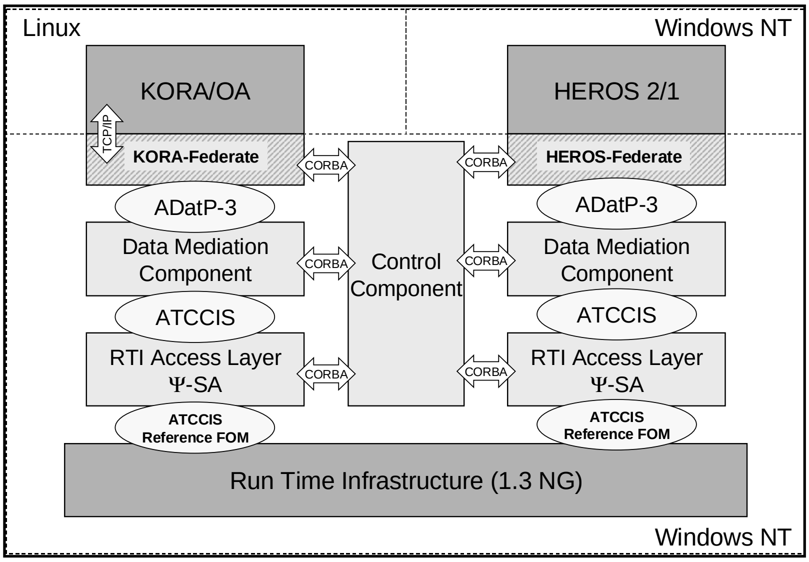

Figure 4: Prototype Architecture

A more detailed description of the technical solution is given in [Krusche et al., 2000]. The details concerning the DMF module can be found in [Krusche and Tolk, 1999]. The first publication of the architectural concept can be found in [Tolk, 1999]. More details concerning the problems of data alignment and data management as well as respective technical solutions and tools can be found in [Tolk, 2000a] and [Tolk, 2001]. Within the US, similar efforts – especially in the Army domain – are described in [Hieb and Blalock, 1999] or [Timian *et al.*, 1999].

3.2.2 The German R&D Efforts on a Command and Control to Simulation Proxy Solution (C2Sim-Proxy)

The information integration platform developed in the R&D study Decision Support Tools was very simulation oriented. Consequently, the C4I community was not convinced to use this approach (although in [Krusche and Tolk, 1999] as well as in [Tolk, 2000a] or [Herzog et al., 2000] it is shown that this solution isn't bound tightly to the RTI and not even to HLA but is an open information or data driven federation solution). Therefore, the overall idea proposed by the C2Sim-Proxy is to bridge the

[4] ATCCIS = Army Tactical Command and Control Information System; LC2IEDM = Land Command and Control Information Exchange Data Model. The LC2IEDM is the standardized version of the former ATCCIS data model [NATO, 2000].

gap between the C4I systems world and the simulation systems world by connecting their respective standardized information exchange solutions with each other.

The C2Sim-Proxy study can be seen as the logical prosecution of the works initiated by the Decision Support Tools study. It was conducted on behalf of the WTD81 by the same team having done the work before. In general, the prototype of DST II was accepted for the simulation world. However, as C4I developers hardly will agree to use the HLA/RTI as a software communication bus for their systems, the task of the C2Sim-Proxy was to connect the DST information integration platform prototype with respective standard components on the C4I systems side.

The first challenge was to find a standard component for information exchange within the C4I domain. As the most promising effort, the Multinational Interoperability Program MIP was chosen. MIP has been started in April 1998 with the aim to achieve international interoperability of Command and Control Information Systems (C2IS) at all command levels - from corps to battalion (or lowest appropriate level). It comprises two Phases:

- Phase 1 that achieves interoperability by a Message Exchange Mechanism (MEM)
- Phase 2 that uses a Data Exchange Mechanism (DEM).

Both MIP Phases are based on the Land C2 Information Exchange Data Model as the MIP Common Data Model (MCDM). Therefore, a promising candidate was found.

Next thing to do was to couple the information integration platform of the study Decision Support Tools with the MIP environment. To do this, the ATCCIS replication mechanism (ARM) was used. This led to the following situation:

- On the simulation systems' side, the RTI was used for communication. The OMT version of the ATCCIS data model was used as a FOM.
- On the C4I system side, the ARM was used doing data replication based on the ATCCIS data model.

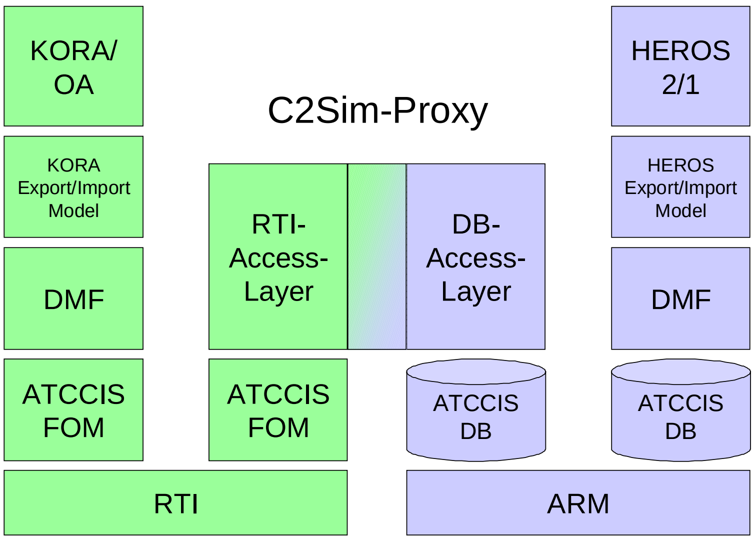

Figure 5: Experimental System

In other words, the C2Sim-Proxy had to look like a federate from the simulation side as well as like a data replication target from the C4I side. The C2Sim-Proxy just had to connect the target database of the ARM with the ATCCIS FOM on the RTI. As the information objects are equally structured (both side are using more or less versions of the same information structure model), there is no translation or mediation concept necessary. Figure 5 shows the experimental system used to present the ideas of the C2Sim-Proxy at the end of the respective R&D study in December 2000.

It may be also worth to mention that the prototype of the C2Sim-Proxy was implemented in only two months by three companies. This was enabled by the clear modular design based on standardized and well defined interfaces allowing the team to "plug in" additional layers or modules as well as the distributed development and testing. A more detailed description of the technical solution is given in [Menzler et al., 2001]. This project is part of the German contribution to the US/GE simulation-to-C4I coupling efforts within the project SINCE.

3.3 Decision Support for the Artillery

The steady increase of the flood of information as well as the increasing complexity of the artillery systems complicate more and more the C2-process. Advances in the area of modern technology will also influence and have to support the C2-process within the artillery branch. In order to optimize the process of Reconnaissance – Command – Effect, the artillery commander and his staff must be supported by information technology. For this purpose the weapon command and engagement system ADLER was developed. These systems improve the tactical – operational command performance due to the improved reporting, information exchange and information processing systems. Subsequently, coordination and decision preparation are therefore improved. The primary goal is to improve the reaction time and precision of the command and control processes during an engagement. It is equally important that artillery commanders and their staff are properly equipped with decision support tools. In the recent years an analysis tool was developed, that supports the evaluation of new artillery systems and ammunition with respect to combat, lethality, fire power, logistic issues and so on. This system SMArAGD is principally applicable to support the command and control process. This model was not primarily developed for this task and therefore requires a relatively large level of effort to use. In order to use this tool in the combat control centers, the simulation models and associated modules need to be properly configured for this intended purpose.

Within the framework of this particular study four different task areas are investigated:

1. The system has to analyze an order on division level with respect to the commander's intent and the respective orders for the artillery
2. The system has to demonstrate by the realization of a prototype that a proposal for locations of the own artillery systems like rocket launchers and howitzers as well as target acquisition components with respect to the possible target areas can be done.
3. This has to be done with respect to the opponent forces as well.
4. The execution of the simulation component yields insights about the possible choke points, logistic requirements and so on.

4 Summary

Decision support will become a more and more major point in the deployment of forces in Article 5 and Non-Article 5 - operations as well. Providing C4IS to military commanders require DSS in the same way in order to exploit the information superiority to C2-superiority. Decision support systems will relieve the military commander of simple decisions and allow him more freedom action for his real Command and Control tasks and complex decisions. Although some functionality required by the military are already feasible there is still a long way to go to provide field usable tools, which have successfully passed the validation criteria. The interoperability of collaborating systems becomes a major issue in coalition forces with shared information sources and international mixed divisions and Corps. The problems do not range only in architectural and data considerations they also cover the coping of modeling the special features in peace support operations like the current deployments in former Yugoslavia. The German Military in cooperation with the industry and academia hasn't solved all problems, but we got started in a very successful direction.

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