Paper

Interfacing war game simulations with tactical C2 systems – dream or reality?

Milan Šnajder and Philip W. Holden

Abstract — Decision making process in current tactical C2 systems is base on planning process of commanders and their staff. Improving tactical decision making by interfacing war game simulations with tactical C2 systems is achievable. Commander can review the results of the simulation and subsequently modify the tactical plan. Previously, the use of "training" simulations was not a viable solution to real world decision making due to the lengthy time required to input all of the combat entities, the unit organizations and personnel dispositions, the equipment configurations, status of the units and equipment, and the distribution of the available supplies. Modern C2 systems have all of this information stored in the common system databases, and this information can be used to instantiate and populate the simulation through an electronic adaptation of the data structures to match the requirements of the constructive simulation. This paper will provide description of system approach of interfacing simulation and C2 system to improve decision-making.

Keywords — C2 systems, war fighting simulation, GF-TCCS, common operatring picture, NCOE, system architecture, constructive simulations ModSAF, SAF, SIMNET CGFs, OTB, DIS, HLA, evolutionary system development, rapid prototyping, interfacing ModSAF with GF-TCCS, MOD, friendly and enemy forces, tactical operations centre.

1. Introduction

The Army of the Czech Republic (ACR) is developing an integrated, automated ground forces tactical command and control system. Previously, commanders and staffs generally performed their mission using a manual system, augmented by some commercially available hardware and software systems. Some automation and communications systems operated in an isolated manner but did not provide the mobility, functional flexibility, security, survivability, and interoperability required to support the ACR. The accelerated tempo of modern, mostly alliance-based combined-arms warfare demands rapid processing and transfer of C2 information. Ground forces combat at tactical levels requires improved battle command systems, increased capability to synchronize direct and indirect fire, faster and more comprehensive access to intelligence data, enhanced situational awareness and effective force protection. To improve agility, commanders at all echelons require the means to gain and use timely battle space information in order to make informed decisions in a manner consistently faster than that of the enemy. **The ground forces tactical command and control system** (GF-TCCS) is being developed to meet these requirements, and tools to help the commander in the decision-making process are being developed. One of the more promising is the use of constructive war game simulations to explore and analyze the effects of different courses of action.

The Czech Republic has recently installed the **war fighting simulation, ModSAF** at the Military Academy in Brno, and at the training center in Vyskov. These simulations are being used to train the tactical commanders and staff, and can be used to model various courses of action, providing valuable information to support decision making. The US Government provided the simulation software, and had a contractor, **Science Applications International Corporation** (SAIC), perform the installation of ModSAF in April, 1999. Continuous improvements to the application have been made since that time. As the simulation tools are used, new applications for the simulations are becoming evident, including being able to use the simulation during tactical operations. One of the obstacles to using simulations during a crisis or military operation is the extensive amount of time necessary to setup the simulation. To be effective, the simulation must be loaded with three categories of information:

- locations, strength and status of the friendly forces, and the presumed locations, strength, and status of the opposing forces;
- missions of the respective units;
- environment variables such as terrain and weather.

The integration of constructive simulations with the GF-TCCS will allow the electronic instantiation and parameterization of the simulation with all three categories of information, allowing it to be used in real-time decision making.

2. Ground forces tactical command and control system operational requirements

The GF-TCCS will provide seamless connectivity from the lower tactical (squad and platoon) level to the operational commands (ground forces command and territorial forces command). GF-TCCS will be used regularly within garrison, during deployment, and in the field to maintain the soldier's proficiency at the level required to respond to the broad range of potential missions.

GF-TCCS vertically and horizontally integrates information from tactical to operational command level, and will allow the commander and staff to:

- collect process and organize large amount of battle information;
- combine information from multiple sources to create more complete and useful information;
- process information to analyze trends;
- detect unusual activities, or predict a future situation;
- develop courses of action based on situational factors;
- exchange information efficiently among and within command posts on the battlefield;
- present information as graphic displays and textual summaries.

Fundamental to the GF-TCCS operational concept and relevant **common operating picture** (COP) is a single entry, near-real-time information system, with automated interoperability between each battlefield information system. GF-TCCS provides situational information and decision sup-port to commanders and staffs in the execution of the operational/tactical battle at operational groups and below. The GF-TCCS command and control subsystems are heavily oriented toward combat operations.

The GF-TCCS command and control sub-systems are linked by **tactical area communications system** and by the **combat net radio system**. Combat forces, weapon systems and battlefield automated systems will be supported by the integrated management and control system that provides management of the tactical communications.

GF-TCCS will be linked directly to the staff information system (SIS) ACR, providing the framework for seamless connectivity from the battalion to the general staff.

The NC3 common operating environment (NCOE) is the NATO C3 standard profile (NCSP) for computing and communications infrastructure. The NCSP describes the structural foundation necessary to build interoperable and open systems. The purpose of the NCOE is to facilitate a common understanding of the concepts, constructs and methods (set up processes) required for targeted NATO systems. More detail on the NCOE component model can be found in volume 5 of the NATO C3 Technical Architecture, *NC3 Common Operating Environment*.

GF-TCCS's C2 systems are shown in Fig. 1 and include:

- maneuver control system (MCS);
- fire support control system (FSCS);
- forward area air defense control system (FAADCS);
- intelligence and electronic warfare control system (IEWCS);
- tactical logistics control system (TLCS);
- battle management vehicular information system (BMVIS).

The three supporting systems are:

- tactical area communications system (TACS);
- combat net radio system (CNRS);
- integrated management and control system (IMCS).

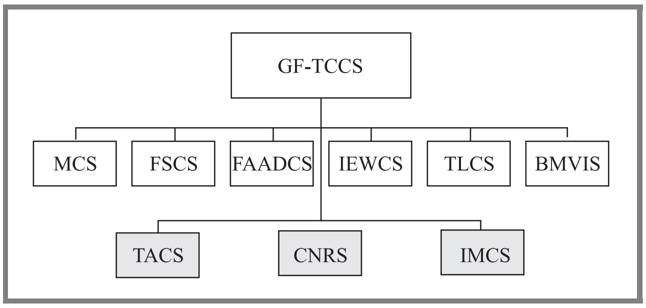

Fig. 1. Subsystems of the GF-TCCS.

The GF-TCCS provides a simultaneous, relevant picture of the battlefield at each echelon – from squad/mobile platform leader to battalion/brigade commander – based on common data collected through networks of command posts, commander's vehicles, computers, sensors and weapon platforms. This information can be used to instantiate or update the data files used by the constructive simulations.

3. GF-TCCS system architecture overview

The GF-TCCS architecture provides two complimentary methods of distributing C2 data within a single, local area command post (CP). Within a local area CP, the GF-TCCS will employ the following message distribution means:

- **event bus architecture** – for message products that are relatively small, requiring a wide distribution, and are time sensitive;
- **product server architecture** – for information products that are larger, less time sensitive, and have a limited or sequential pattern of user access or workflow.

Externally, the GF-TCCS architecture employs an external messaging architecture that provides the following data distribution means:

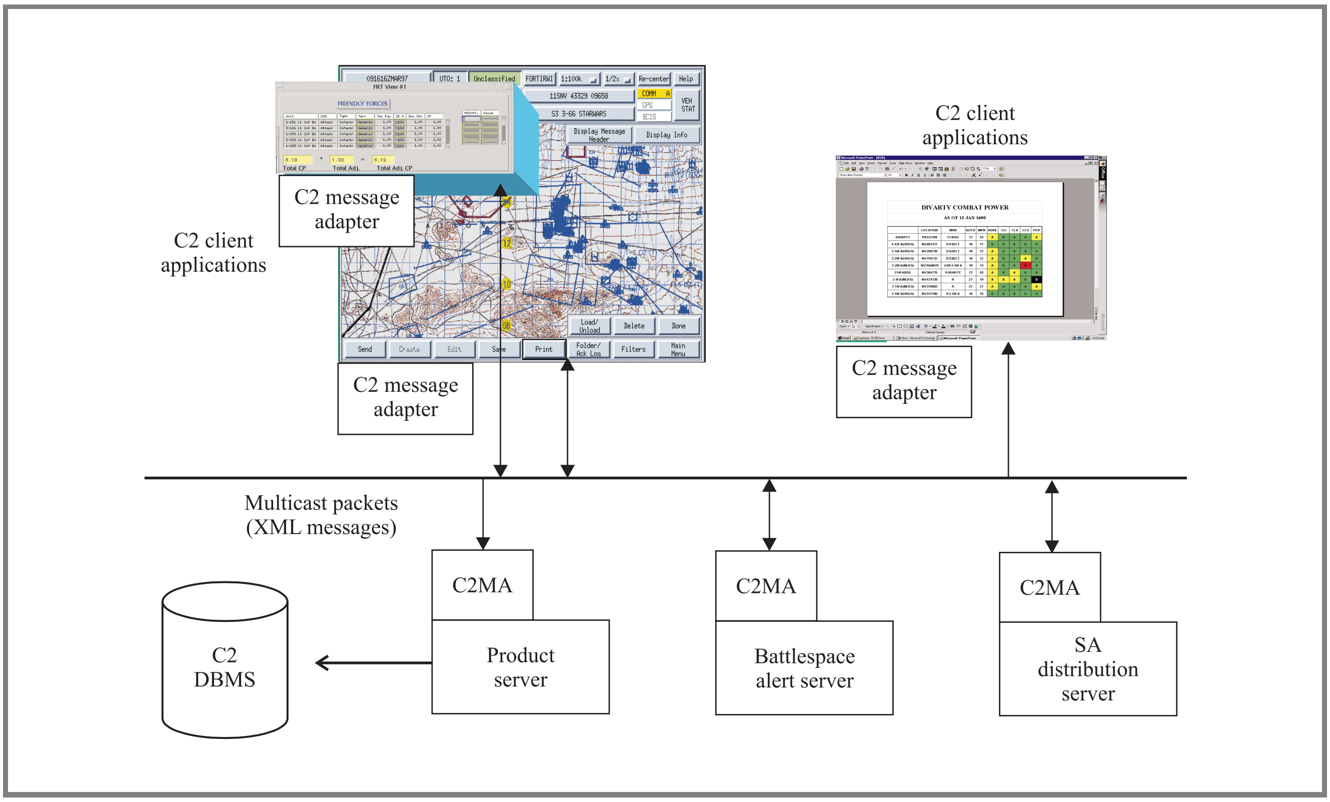

Fig. 2. GF-TCCS system architecture.

- **AdatP-3 messaging** – for NATO interoperability;
- **VMF messaging** – for inter-GF-TCCS traffic, where low bandwidth communication median is available or where low latency messaging is required;
- **XML product messaging** – for inter- GF-TCCS traffic, where a higher bandwidth communication median is available, or where larger bulk messages are required.

The event bus architecture provides a publish/subscribe mechanism to distribute information (i.e., messages) among C2 applications. In a publish/subscribe architecture, applications register themselves as producers of information (i.e., publishers) and consumers of information (i.e., subscribers). Figure 2 graphically depicts the basic connectivity of the GF-TCCS event bus.
Two general component types comprise the event bus architecture. They are:

- C2 message adapters (C2MA) that provide the interface between the C2 applications and the event bus. C2MAs distributes information (XML messages) within a tactical operation center using IP multicast.
- C2 applications that are the domain applications using the services of the event bus. C2 applications may be either client side or server side domain applications, such as the commander's information display (i.e., map) client, the task organization client, and the product data server.

4. Operational-tactical solutions

This group of applications supports all commanders and staff officer tasks. In actual solution stage, operational-tactical solutions (OTS) has about 12 specific applications for supporting typical commander and staff activities:

- TaGIS – Czech Army RETM for-mat and Aerial snap composition;
- transportation on own wheels – output – transportation plan;
- chemical situation awareness;
- planning of the radio-relay communication – schema of connection availability;
- combat power (force ratio calculation) – output;
- radio visibility awareness;
- message handling system – warning preparation;
- OWNSITREP – situational report preparation;
- DMP lifebook – lists of staff activities, software aids and active documents;

Fig. 3. TaGIS – combination of FRAGO, battalion planning overlay and actual UTO.

- TaGIS – combination of FRAGO, battalion planning overlay and actual UTO (Fig. 3);
- electronic staff lifebook – mission definition.

5. The architectural approach of the MCS

Maneuver control system (MCS), is a core tactical forces information system that provides commanders and staff with the capability to collect, coordinate, and act on real-time battlefield information.

Through the MCS, the commander transmits critical battlefield information, courses of action, schemes of maneuver, warning orders, operation orders, priorities, intelligence requests, and air operations requests. The MCS database and data files provide the information necessary to load the simulations with the friendly unit missions and objectives.

The main purpose of the event bus architecture is to distribute and receive time-sensitive battlefield events data (i.e., situation awareness data) between interested C2 applications. It connects the publishers and subscribers of messages together. The C2MA listens for a published message, validates the format of the message, and distributes it to subscribers on the bus through the use of the subscriber's C2MA. The core technology for the event bus is IP multicast, which is a standard IP network-level protocol.

The C2 message adapter is the middle-ware component that provides the event bus services to C2 applications. Its role

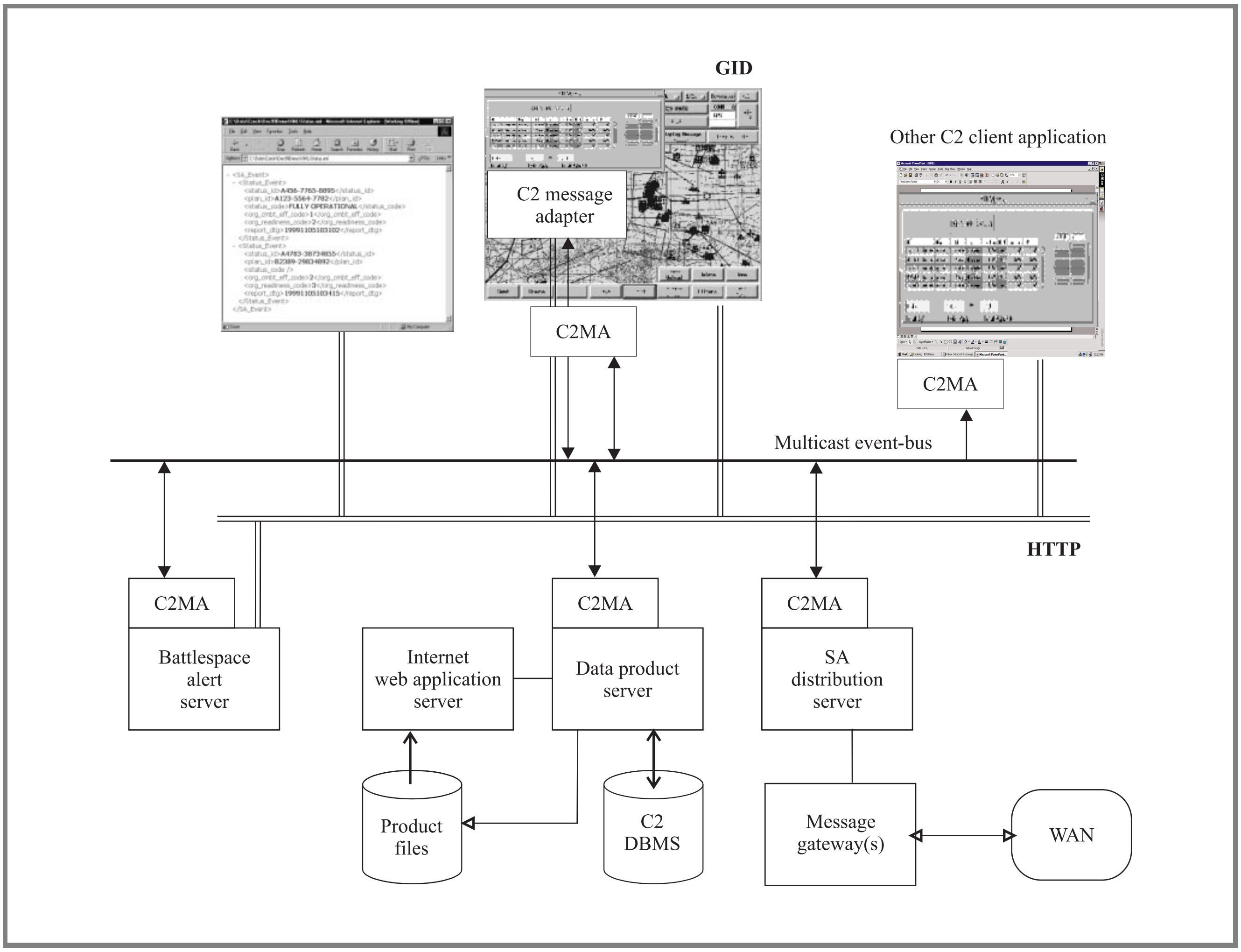

Fig. 4. GF-TCCS event bus architecture and C2 message.

is to handle subscriptions of C2 applications, listen for messages on the bus, and to publish messages from C2 applications.

6. C2 application architecture

GF-TCCS C2 functionality is provided by a set of server-side and client-side domain applications (Fig. 4). Each application component provides a unique set of C2 services that are mutually exclusive to that application component.

The applications components are:

- graphical information display (GID);
- battlefield alert server (BAS).

7. Constructive simulations

Constructive simulations include a category of computer generated forces (CGFs) that simulate battlefield entities and aggregates of those entities. The simulation of the entities includes their physical characteristics, tactical behaviors and decisions processes, and the interactions with other entities. Entities can range from an individual soldier, to ground vehicles such as tanks or armored personnel carriers, to aircraft or ships. The entities can be guided and controlled by human operators using joysticks or keyboards, or full mission simulators such as the SIMNET or CCTT manned simulators, or the entities can be completely generated and controlled by the computer. Entities entirely controlled by the computer are referred to as "automated forces". Where some human involvement in the decision process is involved, they are referred to as "semi-automated forces" (SAF). These simulations are routinely used to support army applications in three modeling and simulation domains: training, exercise, military operations (TEMO); advanced concepts and requirements (ACR); and research, development and acquisition (RDA).

ModSAF has a modular, data-driven architecture that allows the development and integration of specific detailed models that become an additive part of the overall system. ModSAF's main modules are the human interface to the simulation system (SAF station), SAF Sims, the entity, and

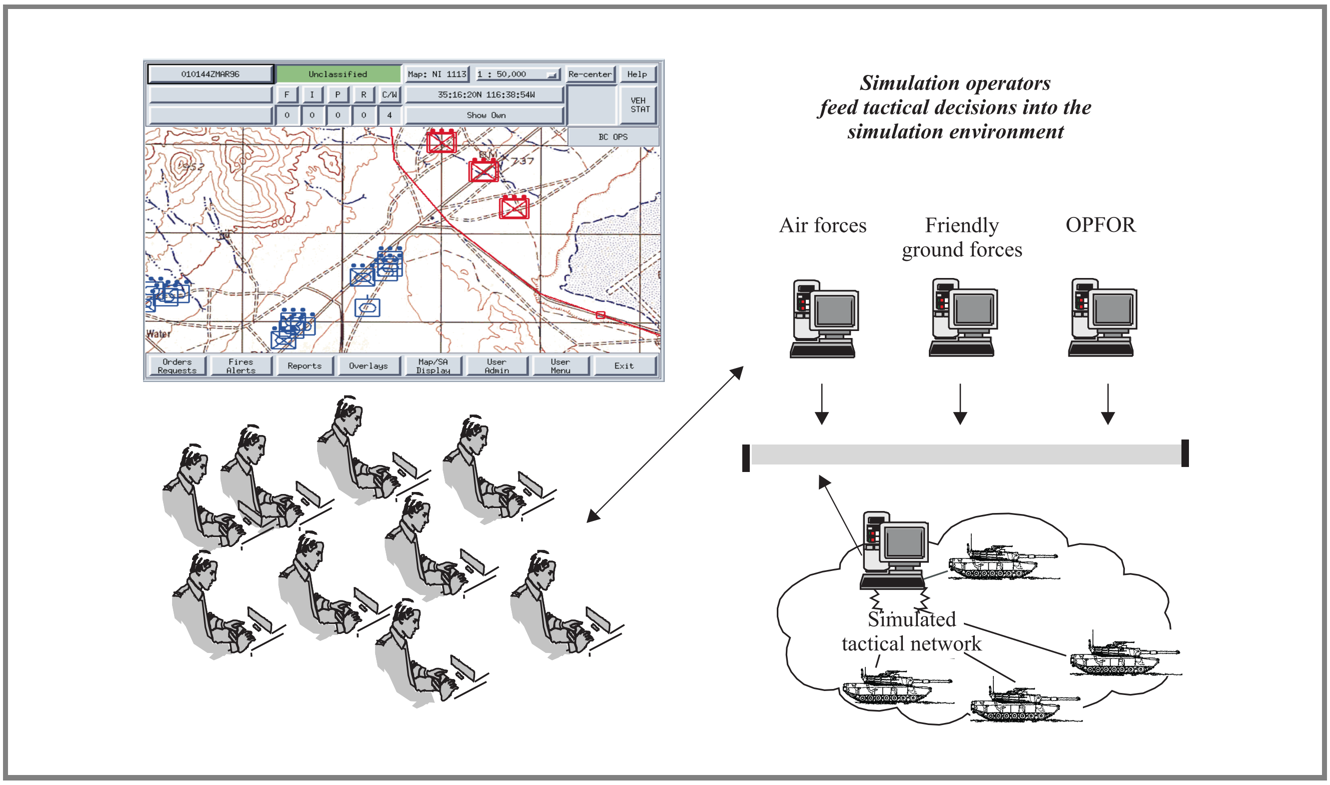

Fig. 5. The typical Czech constructive simulation system configuration.

aggregate models. SAF Sims and SAF stations use a common database to communicate with each other, and use the DIS protocol to communicate with the synthetic environment and other simulations and simulators. The common database provides command and control information for the simulation of organizations, while the DIS communications are oriented to the physical world. The simulation operator has the ability to create, modify, save or load scenario files, overlay files, minefield templates, and other setup parameters. The simulation can also start/resume, stop/pause, and restart an exercise run based on external input in the form of simulation management messages.

8. The Czech simulation system

The Army of the Czech Republic is currently using the US warfighting simulation, ModSAF, at the Military Academy in Brno, and at the training center in Vyskov. The ACR has developed expertise in using and modifying the simulations with the help of the US provided source code for the simulation and advanced developer training courses. The simulation engineers at the Military Academy have developed new capabilities for the Czech simulation system (Fig. 5). The ACR has made a number of enhancements to the simulation system, and developed the capability to build the digital terrain databases necessary to support the modular semi-automated forces (ModSAF) and its successor, the oneSAF testbed baseline (OTB) synthetic natural environment requirements. These enhanced simulations are being used to train the tactical commanders and staff, and can be used to model various courses of action, providing valuable information. The ModSAF simulation system builds upon the previous United States of America Army simulations that started with the simulator networking (SIMNET) program. The original ModSAF incorporated the software code associated with both SIMNET SAF and ODIN (73 Easting) SAF. In 1993, the US Defense Advanced Research Projects Agency (DARPA) began building ModSAF by developing an open simulation architecture, which could be used to create synthetic agents for a variety of distributed interactive simulation (DIS) applications. The initial effort fielded a system in 1993 to support the what-if simulation system for advanced research and development (WISSARD) program, which had a requirement for beyond visual range, air-to-air engagement scenarios. After the initial release, the remaining battlefield operating systems (BOS) and behaviors were added to ModSAF to fill out the synthetic battlefield. ModSAF 1.2 was released in 1994 and included the majority of systems that had been represented in the previous SIMNET SAF version. ModSAF 2.0 followed in 1995, ModSAF 2.1 in 1996, ModSAF 3.0 in 1997, ModSAF 4.0 in 1998 and finally, the last version of the simulation, ModSAF 5.0 was released in 1999. The successor to ModSAF is the one semi-automated forces testbed baseline that will be replaced by the OneSAF objective system, which is planned to be fielded in 2004.

ModSAF has been expanded to include many aspects of the modern battlefield, to include the effects of weapons of mass destruction (WMD). ModSAF can also model the logistics aspects of the engagement, and has the capability to model support functions such as medical support to operations. The highly detailed constructive simulation has the capability to model the evaluation of medical conditions of personnel, and to model evacuation of injured individuals by various means, to include vehicles, and rotary wing aircraft (RWA). The simulation also models personnel status, including wounded in action (WIA) and killed in action (KIA) as a result of casualties caused by munitions, detonations, collisions, and non-combat illness/injury. The simulated injuries can range from smoke inhalation and other environmental affects to death by weapons of mass destruction.

9. Evolutionary systems development and rapid prototyping

Both the development of the GF-TCCS and the ModSAF/OTB simulation systems have benefited from the **evolutionary development process** also known as "spiral development". This development methodology is based on two main fundamentals:

1. **Incremental development**. Both whole complex and each subsystem are (and will be) developed in a sequence of increments. From the first increment, each of them is fully operable and fully integrated with all preceding increments.

2. **Rapid prototyping**. Every planned element and prepared system is prepared like a prototype and consecutively tested in development labs, in a special testbed and in the field as well.

Rapid prototyping, together with experimentation, provides an effective tool for resolving issues, experimental data collection, reducing risk early, and determining the adequacy of requirements, design, and new GF-TCCS's system capabilities before committing major resources.
The attributes of the proposed approach to evolutionary GF-TCCS development include:

- use of software development environments/tools for rapid prototyping of functionality;
- object-oriented design that allow rapid integration of COTS software;
- NATO OSE software standards and practices;
- documentation appropriate for expansion into formal specifications;
- continuous interaction and feedback from the military end-users.

10. Integrating ModSAF with the GF-TCCS

Many companies and organizations use the open architecture ModSAF development environment. The source code can be compiled using the operating system native UNIX C compilers, or the freeware toolset GNU gcc. The ModSAF distribution package includes scripts (awk, sed, lex, etc.) and makes files to support distributed development and experimentation. The US Government provided the ModSAF source code to the Czech Ministry of Defense (MoD) with a distribution agreement that allows unlimited use by the Czech MoD. The simulation engineers at the Czech Military Academy have made several modifications and enhancements to the ModSAF and OTB simulation systems. **The intent of the liberal distribution agreement is to allow the users to develop additional capabilities, as their needs require**. The simulation runs on multiple platforms, including the PC (Linux), Silicon Graphics (SGI), SUN, and DEC Alpha platforms. The computer requirements are relatively low, and the simulation can run on a PC using the Linux operating system with a 300 MHz processor, 128 Mbytes of RAM. This allows integration with the GF-TCCS without the problems normally associated with interfacing different computational platforms. Much of the Mod-SAF simulation software is written in the C language, with Java used for recent additions to the Graphical User Interface. The modular architecture and separate GUI module allow the ability to create a custom user interface using the Czech language. Although there is a strong effort within the ACR to use the English language for interoperability with NATO partners, the ability to have a Czech language interface greatly improves the ease of use for the average Czech soldier.

11. Standards compliance

In order to ensure compatibility with other NATO countries, standards compliance is crucial to the long-term success of the project. Compliance with the NATO modeling and simulation master plan is considered essential, and the simulations must provide support for a standard synthetic environment and be able to communicate using HLA and DIS 2.0.4 protocols. ModSAF meets these criteria for interoperability, although the operation in an HLA environment requires the use of a gateway such as the MaK technology HLA gateway, or the Naval Air Warfare Center – Training Systems Division (NAWCTSD) gateway. The ModSAF simulation appears to be functionally suited for integration with the GF-TCCS since the resolution of entities and the convention for identifying vehicles precludes ambiguity because the provisions for bumper numbers and task organizations is compatible with the ACR requirements and conventions. The capability to simulate dynamic environments, and the capability to assess damage to prepositioned and dynamic objects due to detonations of munitions, provides the level of detail to support the decision making process used at the tactical level.

12. Behavioral specificity

One of the traditional obstacles to using simulations to support decision making in a real-time environment is the extensive time required to create the necessary simulation configuration that reflects the current operational situation. Often, a team of multiple simulation specialists would require several days to create the data needed to represent the situation, and to load that information into the computer. For large and complex scenarios the process can require several weeks to be prepared. In order to support real-time Czech tactical requirements, the process of gathering the information on the current situation and loading the information to start a simulation run must take less than 30 minutes, and preferably less than five minutes. The ModSAF simulation is structured such that the setup and parameter information is contained in data files, and even the behaviors and unit missions can be instantiated on most entities using data file modifications. Many behaviors can be implemented with data strings, and configuration parameters can be used to customize a behavior for a unique situation. Under this approach, behaviors such as those required for a road march can be used on any ground vehicle or ground unit. However, the weapon or vehicle specific behaviors such as the tactical actions that differentiate a tank platoon road march from a mechanized platoon road march are not represented in the generic behavior.

The ModSAF simulation supports three basic types of behavior control: **Pre-planned, operator controlled**, and **automatic reaction**. The pre-planned mode of operation allows the user to specify the sequencing of behaviors for a unit, and allows control of the transitions from one behavior phase to the next. Transitions can be timephased, or caused by actions such as crossing a control measure, commands from the operator, or other simulation events. With the operator control mode, the SAF operator has the ability to modify missions during execution of a scenario, to include making immediate interventions to make temporary modifications to the mission. The automatic reaction mode allows entity reactions that are enabled by data, and when activated, a reaction overrides the current mission with a new behavior. The reaction can be resumed at the direction of the SAF operator.

Behavior models interface with the physical models through defined APIs called **generic model interfaces** (GMIs). GMI facilitates physical model extension, implementing each physical model with one distinct software unit in the form of a C language library, functionally becoming a "plug and play" system, with physical models capable of being easily inserted or deleted.

In order to make an entity such as a T-72 tank move, the movement behavior provides a proper command by calling GMIs supported by the physical model. Then the generic

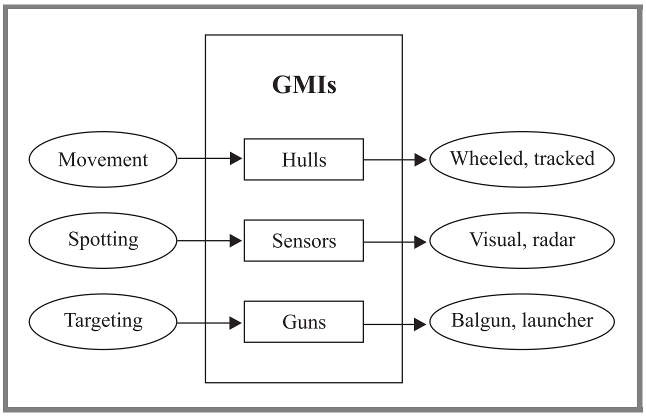

Fig. 6. The GMI provides the physical model invocation.

physical model that interfaces to a specific physical model, calls a proper physical model for implementation. In this case, it is a tracked physical model that has T-72 tracked hull characteristics. Figure 6 shows this relationship. Instead of using the specific model such as a T-72 tracked model, the SAF behaviors use an API that provides generic access to physical models. Thus, behavior models can uniformly invoke functionality regardless of the physical model that executes the invocation.

13. Modeling of tactical electronic and communications systems

The simulation used to support the GF-TCCS must have the capability to model the intelligence gathering systems such as the artillery and mortar locating radars, as well as the electronic intelligence and signal intelligence systems. The ModSAF generic sensor model (GSM) facilitates the implementation of new sensing algorithms. For example, a ground-based sensor can be created that automatically reports activity of targets within a designated area. ModSAF also has a generic radio physical model, that can be used to instantiate any of the existing and planned Czech military radio types.

14. Integration architecture

The concept for integration of the ModSAF simulation with the GF-TCCS is to build a conversion utility that will take the pertinent information from the GF-TCCS databases and insert or modify the information in the ModSAF common data-base. This conversion utility will simplify the existing laborious process of loading and instantiating the simulation, so that the entire process can be accomplished automatically with no manual user interventions. There are major information areas that require conversion and instantiation:

Friendly forces information as it is known and recorded in the GF-TCCS:

- unit table of organization and entity missions;
- unit placement on the synthetic terrain;
- unit strength and supply status;
- vehicle status and supply of fuel, crew, and ammunition.

Enemy force information according to intelligence estimates and enemy order of battle:

- unit table of organization and entity missions;
- unit placement on the synthetic terrain;
- unit strength and supply status;
- vehicle status and supply of fuel, crew, and ammunition.

The information for each of these areas for both the friendly and enemy forces is contained within the GF-TCCS databases. The integration effort is to provide the conversion between the different formats and to expand or augment the data as it is loaded into the ModSAF simulation. In addition, there will be a development process to build the user interface necessary to cause the conversion and data loading, and to integrate the display of the simulation data on the tactical situational display in the Tactical Operations Center (TOC) as the simulation is running.

The VTUE development team that is building the GF-TCCS has been examining the situation with the ModSAF simulation being used at the Czech Military Academy, and the contractor, DelInfo, is using this knowledge for the development of the interface. Presently, the GF-TCCS is in the development stage. The first increment of MCS SW package is used in the Rapid Reaction Forces of the ACR since 2001.

The ModSAF simulation is currently being used to support training exercises at the Brigade and below level at the Military Academy in Brno. The current estimate for the integration of the simulations with the command and control system is for starting the integration in mid 2003, with a demonstration capability available in the first quarter 2004, and full implementation by the end of 2004.

15. Conclusion

This paper has presented an overview of the architecture approach for integrating the ModSAF constructive simulation with the GF-TCCS. The goal of the enclosed architecture has been to present a basic decision support system infrastructure that is both flexible and presents a minimum development risk. This is achieved by leveraging both marketplace capabilities and verified market trends to simplify the information-processing approach and subsequent implementation. The backbone of the architecture is based on internal technology, in particular the HTTP and XML technologies. These technologies, combined with important architectural principals of loosely-coupled distributed computers, are molded into a baseline C2 infrastructure upon which GF-TCCS applications may be developed.

Although there are additional design efforts necessary to move forward, the GF-TCCS architecture represents a significant first step towards creating a base environment for the rapid development of C2 capabilities and software products. This architecture approach is ideally suited to spiral development and incremental upgrades.

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