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This report presents the results of the Digital Collective Training Study, which identifies requirements for the Advanced Distributed Simulation Technology II (ADST II) Program in support of evolving digital battlestaff training needs These requirements are derived from a Digital Collective Training (DCT) approach, which leverages fielded and emerging digital systems to provide a modular, low cost, low risk DCT course of action. The intent of DCT is to allow parallel development of C4I systems, training and doctrine and distributed simulation systems that result in a flexible and tailorable training tool. An implementation plan for a Digital Battlestaff Sustainment Trainer (DBST) driver based on a federation of CCTT SAF and OTB SAF is proposed for train up and execution of the Division Capstone Exercise (DCX) at Fort Hood, Texas. This implementation plan includes a blueprint, support environment, initial capability, and a simulation support concept which best support digital staff training for DCX. Critical DBST functionality required to support DCX includes 1) incorporation of a confederation of CCTT SAF and ModSAF/OneSAF Testbed as a ground maneuver driver in a Digital Battlestaff Sustainment Trainer (DBST) for DCX train up from November 1999 through March 2001 and 2) use of a confederated CCTT SAF and ModSAF 5.0/OneSAF Testbed maneuver model as a Low Overhead Driver for a Staff COFT in the CCTT TOC facility during DCX in March 2001.

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Executive Summary

This report presents the results of the Digital Collective Training Study, which identifies requirements for the Advanced Distributed Simulation Technology II (ADST II) Program in support of evolving digital battlestaff training needs These requirements are derived from a Digital Collective Training (DCT) approach, which leverages fielded and emerging digital systems to provide a modular, low cost, low risk DCT course of action. The intent of DCT is to allow parallel development of C4I systems, training and doctrine and distributed simulation systems that result in a flexible and tailorable training tool. An implementation plan for a Digital Battlestaff Sustainment Trainer (DBST) driver based on a federation of CCTT SAF and OTB SAF is proposed for train up and execution of the Division Capstone Exercise (DCX) at Fort Hood, Texas. This implementation plan includes a blueprint, support environment, initial capability, and a simulation support concept which best support digital staff training for DCX. Critical DBST functionality required to support DCX includes 1) incorporation of a confederation of CCTT SAF and ModSAF/OneSAF Testbed as a ground maneuver driver in a Digital Battlestaff Sustainment Trainer (DBST) for DCX train up from November 1999 through March 2001 and 2) use of a confederated CCTT SAF and ModSAF 5.0/OneSAF Testbed maneuver model as a Low Overhead Driver for a Staff COFT in the CCTT TOC facility during DCX in March 2001.

The recommended approach is the development of a federation of CCTT SAF and OTB utilizing a bridge for communications. This federation would make use of a geographic partitioning approach for supporting DBST exercises that would provide the validated behaviors of CCTT with the wide variety of systems and behaviors provided by OTB. Scalability and interoperability of the SAFs are the key areas that must be addresses in order to insure success.

1. Introduction

1.1 Purpose

The purpose of this report is to present the results of the Digital Collective Training Study, which identifies requirements for the Advanced Distributed Simulation Technology II (ADST II) Program in support of evolving digital battlestaff training needs[1]. These requirements are derived using a Digital Collective Training (DCT) approach, which leverages fielded and emerging digital systems to provide a modular, low cost, low risk DCT course of action. This report includes a blueprint, support environment, initial capability, and a simulation support concept which best support digital staff training for DCX. Critical DBST Staff COFT functionality required to support DCX includes 1) incorporation of a confederation of CCTT SAF and ModSAF/OneSAF Testbed as a ground maneuver driver in a Digital Battlestaff Sustainment Trainer (DBST) for DCX train up from November 1999 through March 2001 and 2) use of a confederated CCTT SAF and ModSAF 5.0/OneSAF Testbed maneuver model as a Low Overhead Driver for a Staff COFT in the CCTT TOC facility during DCX in March 2001.

1.2 Contract Overview

The Digital Collective Training Study was performed as Delivery Order (DO) #0106 under the Lockheed Martin Advanced Distributed Simulation Technology II (ADST II) contract with the U.S. Army Simulation Training and Instrumentation Command (STRICOM).

2. Digital Battle Staff Training Overview

The Army is implementing digital command and control systems from platoon level through Corps and echelons above Corps. These new digitized systems include Situational Awareness (FBCB2) at the lower tactical level (Battalion and Below), and the upper levels using the Army Tactical Command and Control System(ATCCS). Although there are many live, virtual and constructive simulations for mission training, a need exists to train commanders and staff to perform their tasks using these new digital systems, especially to train for collective tasks.

Past and current digital exercises such as Synthetic Theater of War – Army (STOW-A) and Fire Support Simulation Trainer (FSST) have focused on demonstrating the capability of driving C4I systems with simulations. FireSim XXI, developed by the Depth and Simultaneous Attack Battle Lab, Fort Sill and fielded by the NSC and STRICOM, has demonstrated the possibilities simulation can provide to the training community. The focus of FIRESIM XXI has been on developing the digital messaging for the Fires Battlefield

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[1] Through out this document, we refer to training system. This is largely due to the principal interaction the warfighters have had with simulation system have been with training systems. DCT is not limited to training exercises, rather the focus in on staff in the loop exercises. Be they for training, weapons / tactics evaluations, or concept exploration the simulation system does not know or care.

Operating System (BOS). DBST proposes to build upon this success by fielding a ground maneuver driver simulation to stimulate the Army Tactical Command and Control (ATCCS) with situational awareness and messaging from maneuver units.

A digital staff training strategy is being created by TRADOC which ranges in level from individual development through collective training with staff drills and section training, to full CP training. For Level II and III drills and staff section training, TRADOC is developing a Staff Conduct of Fire (Staff COFT)/Low Overhead Driver (LOD) training system concept. The digital battle staff training challenge involves designing a set of evolving technical solutions which meet the requirements of this battle staff training strategy and enables development of digital staff tactic, techniques and procedures (TTPs) on still-being-fielded digital hardware and software. These technical solutions need to leverage fielded and emerging legacy-based models, after action review (AAR) tools, interface devices, and confederations. A key challenge is for such digital training systems to be consistent and scaleable between training levels to ensure training transfer.

This study validates that the Digital Collective Training (DCT) approach best meets digital battle staff training needs for Staff COFT/LOD by providing a realistic integrated digital training environment where the commander, staff, and units build understanding and confidence that the TTP and tasks they perform in the simulation environment actually work in the field. The study first reviews the Army's evolving digital staff training strategy and training level requirements. The DCT concept is then explained in terms of addressing these training needs. Critical DCT legacy and evolving components are introduced and exercise results from existing components are presented. A course of action recommendation is made for ADST II requirements to support near-term training system implementation. A DBST training course of action, including blueprint, support environment, initial capability, and a simulation support concept are described which best support digital staff training during train up and execution of the Division Capstone Exercise (DCX) at Fort Hood, Texas. Cost is addressed in terms of the integration and development support required to provide varying levels of C4I stimulation capability through the use of the low overhead driver.

3. Assumptions

3.1 General

Building a system that will train every warfighter in the US Army for every possible contingency is an intractable problem. However, by making certain assumptions, setting bounds and focal points, a cost efficient system can be developed that will meet the needs of the C4I training community.

a) The primary focus will be on the interaction of humans using the tactical C4I system as opposed to simulated representation of commanders and staffs (Virtual Command Posts).

b) The schedule will be driven by the fielding plans for the C4I digitization systems.

c) A division structure or parts of a division structure is the unit size of interest. The minimum force is a Battalion Task Force, then a Brigade, and then two Brigades with Division/Corps slice.

d) Exercise will be conducted on real and simulated (geospecific) terrain of Fort Hood and the NTC.

e) A collective training strategy to maintain proficiency with C4I systems will require a simulation (cost and opportunity to train only in the field is not supportable) and some fixed infrastructure.

f) Existing and developing simulation systems (Close Combat Tactical Trainer (CCTT) and the OneSAF Testbed Baseline[2] (OTB)[3]) will support the exercises.

g) The simulation objective is to minimize new systems development and to leverage the ongoing efforts. A stay behind collective training system for command and control is desired.

h) The initial focus will be on maneuver combat units followed by combat support and combat service support.

i) C4I systems will continue to evolve and specific point to point interfaces will be required to send and receive messages to the C4I systems.

3.2 Government Furnished Resources

Required GFP/GFI that is not currently part of the ADST II property inventory or is not currently contained in the ADST II Master Library has not been positively identified for this effort. It is anticipated that the ADST II C4I and SAF Laboratories will be used for some aspects of this delivery order.

a) In support of this effort the Government will provide coordinating draft 4th Infantry Division Digital Battlestaff Sustainment Training (DBST) Requirements and other user requirements documents collected by the National Simulation Center (NSC) regarding DBST and Staff COFT.

b) The Government will provide access to the NSC Laboratory's parallel effort investigating the Battlefield Functional Area (BFA) and SAF functionality of CCTT SAF and ModSAF 5.0 (current capabilities) and copies of all post-assessment reports.

c) The Government will provide access to CTSF, NSC, STRICOM, and PEO-C3S personnel engaged in providing current DBST and Staff COFT prototype solutions at Fort Hood, Texas for assistance in performing this DO.

d) The Government will provide results of the STRICOM/NSC sponsored SAF Assessment for DBST.

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[2] OTB is the system derived from Modular SemiAutomated Forces (ModSAF).

[3] The Combined Arms Tactical Trainer SemiAutomated Forces (CATT SAF) and the OTB are programmed to merge and become OneSAF. As we will see later in the document, this program is supportive of an early fielding of OneSAF.

3.3 Other Digital Interface/Infrastructure Assumptions

a) Existing "middleware" products such as the Tactical Simulation Interface Unit (TSIU), Protocol Interface Unit (PIU), and the Situational Awareness Tactical Internet Data Server (SATIDS) will be provided to translate from DIS PDUs to the required tactical message format. Development of middleware products is not a cost factor in this study.

b) The current infrastructure at Fort Hood is in place to provide connectivity between the fixed C4I sites (such as the CTSF) and the Fort Hood CCTT facility.

c) All C4I related hardware and software will be provided GFE. Installation and integration of the C4I systems is not a cost factor in this study.

4. Digital Staff Training Concepts

4.1 Army Digital Learning Strategy

As a byproduct of 'digitization', the U.S. Army Training and Doctrine Command (TRADOC) has been evolving its training strategy to meet the challenge of learning and sustaining digital skills. That effort has produced a Digital Learning Strategy and a design approach for a Digital Division Learning Program. This strategy and approach are part of an evolutionary process which incorporates lessons learned and reflects changes in new doctrine, technologies and learning methodologies. It is important to understand that requirements derived from this training strategy should be used as the basis to drive near-term and long-term digital system solutions to assist in training the commander and battlestaff. TRADOC digital training concepts are represented below in Figure 1.

The right portion of the figure represents the Digital Learning Strategy, which has a three-step approach to individual and group battlestaff training. The objective of step one is to become proficient in the 'basics'. Concerning battle command/staff learning, step one involves knowing the Military Decision Making Process (MDMP), proficiency in the tasks, conditions, and standards (TCS) of individual or section/cell tasks, and competency in basic unit warfighting doctrine. The objective of step two is to become proficient in the TCS of both the hardware and software of 'digitization' in the execution of a tactical warfighting scenario. Step two encompasses both vertical and horizontal Battle Command/Staff Training (BCST), such as the Central Technical Support Facility (CTSF) effort at Fort Hood for the FBCB2 Limited User Test (LUT). The objective of step three is distributed learning through the use of training support packages (TSPs) to develop 'hyper-proficient' individuals, teams, and leaders. Step three training involves continuous learning and improvement using interactive, intense, immersion-based experimental observation and execution. The left portion of Figure 1 represents TSP battlestaff training levels being created by TRADOC which range from individual development, through staff drills and section training, to full CP training.

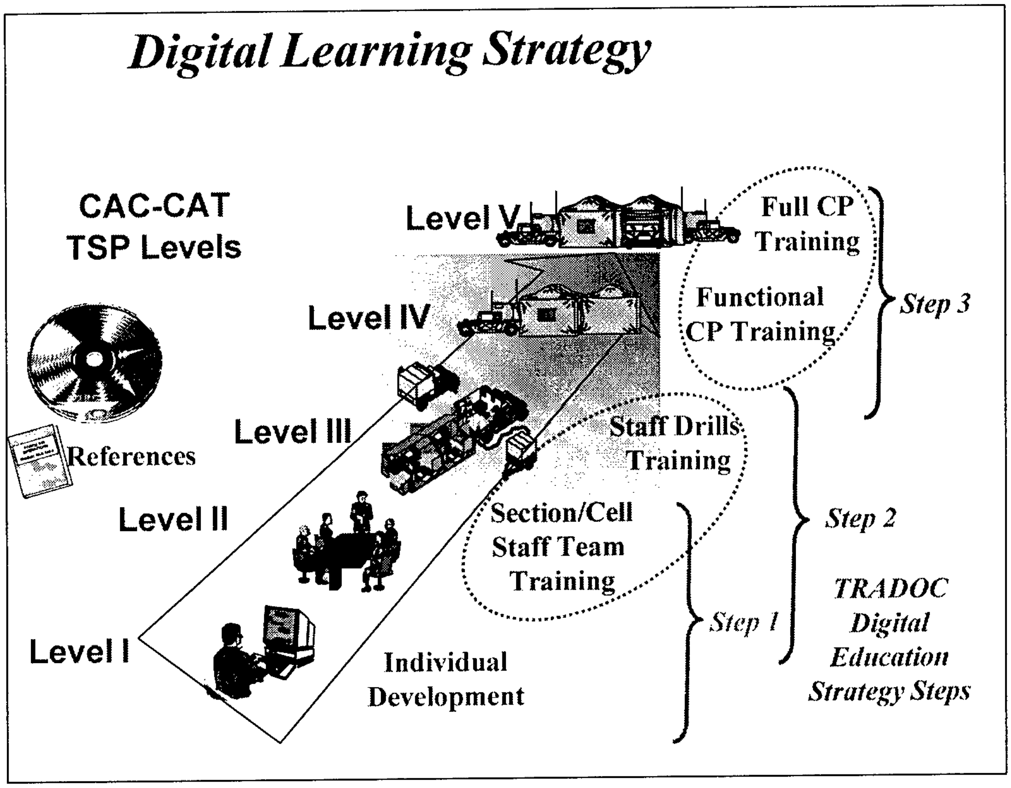


Figure 1 TRADOC Digital Training Concepts

To address current battlestaff training deficiencies, TRADOC is developing a Staff Conduct of Fire (Staff COFT)/Low Overhead Driver (LOD) training system concept, which focuses on TSP Levels II and III as well as on Step 2 of the Digital Learning Strategy. The Staff COFT/LOD methodology uses structured training modules and vignettes, is targeted towards specific Level II/III training objectives and audiences, and is not focused on free-play, force-on-force simulation as are higher level CP exercises. The battalion and above thrust of this effort, which involves battle command/staff learning, is not currently well supported and therefore is likely to involve new systems integration. A number of specified and implied requirements are derived from the higher levels/steps of this digital battlestaff training strategy and these are described below.

4.2 Identified Digital Staff Training System Requirements

The U.S. Army's National Simulation Center (NSC) has conducted recent assessments to determine capabilities required for digital battle staff trainers at brigade level and below (NSC, 1999). This assessment incorporated formal TRADOC and 4th Infantry Division guidance with input on digital staff training needs as viewed by brigade and below commanders and staff. Results from digital force fielding events, such as Task Force XXI, DAWE, and FBCB2 LUT were incorporated as well as ARI research reports related to digital staff training. The NSC has recognized a gap in digital staff training and has designed a digital battle staff training concept to meet this need. The concept calls for two levels of trainers that would be built to bridge the current gap between collective staff training and the high tempo WFXs and CTC rotations. These two training level concepts are being called Staff COFT and Digital Battle Staff Trainer (DBST). Conceptual prototypes (straw-men) of the trainers were constructed to conduct requirements assessment and these preliminary requirements are useful in deriving criteria for this Staff COFT/LOD analysis. Two potential trainers are under consideration, the Staff COFT and the DBST (full-CP trainer). They are distinctive in terms of scale and scope. The two are conceived as complementary to each other as each targets portions (steps or levels) of progressive digital staff training. It is conceivable that the two can be integrated as one DBST. Preliminary system requirements are briefly described below, along with digital staff training requirements derived from other Army sources.

4.2.1 Staff COFT/LOD Requirements (Level II-III Battlestaff Training)

The following describes the key capabilities of the Staff COFT/LOD battlestaff training concept.

Site: The COFT is a fixed "generic" BCT/TF TOC. ABCS equipment will be installed in the facility and communication links hard-wired. The user is not required to provide any equipment. Supplemental items (laptops, charts, etc.) will be a user option.

ABCS Stimulation: A simulation driver replicates reality for the units as it feeds the ABCS suite applicable to the TOC being trained. The various systems light up and have a high degree of inter-activity (messaging and database population) needed for the execution phase of staff actions. Capability includes near or fully functional MCS, ASAS, AFATDS, AMDWS and CSSCS. FBCB2 input would be simulated by the driver (no FBCB2 screens actually in the TOCs).

Support: The unit uses from 0 to 4 personnel to set up and observe/control. Contractor support can range from 4 to 6 depending upon the complexity of the exercise. In some cases, the unit may choose to operate at a very low overhead rate for such events as staff section drills.

Scenario Capability: Multiple scenarios will be created and stored with the Staff COFT. New scenarios can be created and tailored to unit preferences. Terrain database selection can vary from the NTC to Korea, SWA or local. Missions trained can vary by type and phase. For example, meeting engagement, attack or defend with selective focus on all or a given portion of the fight. Implied in the term "COFT" are certain limitations with regard to interaction with OPFOR. The OPFOR play is non-competitive. The unit can in advance tailor or create the scenario and regulate the degree of difficulty.

Training Considerations: The COFT is designed to train basic digital staff tasks that target building proficiency in individual and crew-type C4SI skills. The training is best conducted via vignettes that can be repeated as desired by the senior trainer. Duration of the training sessions will probably be in 2 to 4 hour increments. The trainer has a comprehensive and flexible automated AAR capability that allows printed or digital take-home packages.

4.2.2 DBST Requirements (Level IV-V Battlestaff Training)

The following describes key capabilities identified for the DBST battlestaff training concept. These requirements are important, since it is conceivable that the two digital staff training levels can be integrated as one DBST

Site: Unit sets up TOC portion of one or more command posts. There is maximum flexibility for locations (simulations center lot, motor pool, field). The unit uses organic equipment (to include ABCS) and sets up TOC per its SOP. Tactical communications are used to extent possible depending on location and distance from the simulation drivers.

ABCS Simulation: The simulation driver replicates functionality of ABCS suite to the extent possible. Situation awareness (common operational picture) is via simulation/stimulation interface to include replication of reality for FBCB2 feeds. ABCS inter-activity includes normal staff operational functions (messages, database) in reaction to two-sided tactical events. Normal TOC capability is MCS, ASAS, AFATDS, AMDWS. If ALOC or Log Ops is linked, CSSCS can be stimulated through links to MCS.

Support: Relatively low overhead is the norm which is dependent on size and scope of the exercise. Unit operators will range from none to 4. Contractor support will range from 4 to 10 on average. Ideally, high overhead unit functions like pucksters will be eliminated. Unit communications support for setup will be required in most cases.

Scenario Capability: Multiple scenarios on varied terrain is possible and can be tailored to unit desires. Terrain can be varied from NTC to Korea, SWA or local. The full range of tactical missions can be accommodated to include high resolution focus on specific phases such as the counter-reconnaissance fight of a deliberate defense. OPFOR is competitive and play is fully two-sided with OPFOR played by contractor overhead or unit. Degrees of difficulty, tempo, entry points, iteration length, repetition can be tailored to fit the unit's desires.

Training Considerations: The DBST can range all levels of staff training from crawl to run (Steps 1 through 3). It is best used in a progressive format following basic skill proficiencies gained in the CTSF and Staff COFT. This trainer can be used for up to 7 days of exercise, and is ideally suited for 1 to 3 day scenarios. Multiple CP exercises are possible (brigade TOC with full or partial task force TOCs). The unit requirements will include pre-exercise creation and tailoring of scenarios setting that are targeted at the exercise training objectives. Automated AAR materials will be provided to the senior trainer and unit observer/controllers.

4.2.3 Other Digital Learning Strategy Requirements

TRADOC has developed a Digital Learning Strategy (TRADOC, 1998), which identifies Step Two training programs encompassing vertical and horizontal Battle Command/Staff Training (BCST). Staff COFT training concepts can be used for such Step Two training and therefore, TRADOC Digital Learning Strategy Step Two Characteristics are relevant to Staff COFT capability requirements. TRADOC Digital Learning Strategy Step Two Characteristics include: 1) training on equipment (FBCB2 and ABCS as appropriate 2) explicit tactical warfighting exercises with seamless integration (vertical and horizontal) 3) embedded performance assessment and 4) tailorable simulation execution (stand alone or networked). NSC's Training With Simulations (NSC, 1999) lists C2 requirements for simulation which are also applicable to Staff COFT/LOD. These C2 simulation requirements include scenario realism, neutrality to decision making processes and the ability to free play staff and exercise events. Other implied requirements issues for a Staff COFT concept include support of and training transfer between multiple TSP training levels and the level of C4I/M&S integration.

5. Digital Collective Training

5.1 DCT Concept of Operations

Training is easy. Cost efficient and worthwhile training is much harder. The lack of a family of tools, or product line, that can suit the user's needs as they progress though a series of exercise make supporting training complex. Digital skills appear to deteriorate more rapidly than analog skills. This requires a cost efficient approach to training that reinforces those critical digital skills for the warfighter to be successful. For the sake of discussion, Table 1 presents a series of training levels a user goes though when a new C4I device is introduced into an armored vehicle. It is important to realize that if the user has not seen it, it is a new device, regardless of how long it has been in the inventory.

Task	Training Level	Objective	Location	Supporting Tools
1. Familiarization	Level 1	To understand the symbology and switcholgy of the device.	Day Room	Scripted message generator
2. Focused Use	Level 1 / Level 2	To use the device in a realistic manner. The user only has to deal with this one device.	Day Room / Motor pool.	SAF system to drive the device.
3. Task Loaded Use	Level 3 / Level 4 / Level 5	To use the device in a task loaded environment.	Simulation Facility	Device mounted in a simulator with supporting SAF and other simulators.
4. Field Use	Level 4 / Level 5	To use the device under "real" conditions.	Live Range	A complete field exercise
5. Proficiency	Level 1 to Level 4	Repetitive usage of the device to maintain skills	Varies	Depending on the use case.
6. Reinforcement	Level 1 / Level 2 / Level 3	To selectively reinforce certain aspects of the device	Varies, most likely being the Day Room and Simulation Faculty	A library of scenarios and events to generate the desired user action.
7. Evaluation	Level 1 to Level 5	To measure the user's performance using the device	Varies	Logging and playback capability

Table 1. Purposes of Use

Tasks 1 through 4 establish a gate based training strategy. The user must achieve a degree of proficiency at a level before they are allowed to proceed to the next level of training. It should also be noted that the cost of the training goes up for the first four rows as well. By establishing the gate based training system, we have established a cost-effective means of delivering the training to the user. This allows the application of training dollars to the most effective payoff area.

5.2 Critical DCT Components and Exercise Results

While not a component in the traditional sense, the single most important part of the DCT approach is the training strategies. They provide the foundational support for a set of requirements that serves as a basis for the software and hardware component operations and interactions. At run time, the training strategy dictates the use case and scenario. These, in turn, dictate which software and hardware components will be used. The training strategy drives the requirements for the supporting systems.

The operational C4I system, FCBC2 and ATCCS, are the principal user interfaces. It is though these devices that the commanders and staffs will view the both the real and synthetic world. As such, the simulation must be consistent with the C4I devices.

The simulation systems are supporting devices that provide a means of generating the entities in the battlespace, digital messaging to the C4I systems, and feedback to the training audience by executing the scenario. The two entity-based simulation systems proposed under the DCT concept are a confederation of CCTT SAF and the emerging OneSAF Test Bed. The organization of these SAFs into a confederation is training objective and scenario dependent. The OneSAF Test Bed provides a wide variety of entities with varying levels of behavior maturity. The CCTT SAF provides ground based maneuver entities with validated behaviors. These systems are scheduled to merge into OneSAF over the next four years. A detailed discussion of this is provided in section 6.

An interface system provides the connectivity and message translation capability between the simulation and C4I systems. The interface typically receives and analyzes simulation traffic (DIS PDUs) to determine what C4I messages should be generated and where the message should be routed. These interfaces are currently standalone systems but, with the creation of C4I – simulation standards may be embedded into the simulation in the future. Currently, for the upper tactical internet, the Tactical Simulation Interface Unit (TSIU) provides the ability to create various message formats (JVMF, VMF, et al.) from DIS. The TSIU relies on the use of signal PDUs to create these messages. These unique PDUs are typically generated using the C4I surrogate or the Extended Air Defense Simulation (EADSIM). The Situational Awareness Tactical Internet Data Server (SATIDS) provides connectivity from FBCB2 for the lower tactical internet. It creates VMF messages from DIS PDUs and provides the situational awareness location information for all friendly units. For the DBST, the role of FBCB2 is dependent on the unit being trained; units are at different levels of digital capability, some having FBCB2 some not. For FBCB2 equipped units, FBCB2 “like” situational awareness must be provided to the training audience. This can be provided with actual FBCB2s or a simulation. In either case, the simulation environment must be robust enough to react to either situation.

In order to minimize the amount of negative training, all components of the system must operate in a common synthetic natural environment (SNE). This requires that not only do the simulations share a common environmental representation but also the same representation is used on the C4I systems. One of the key aspects of a common SNE is the ability of the unit to practice in simulation then run the same exercise out in the field. In doing this, they can see places where DCT has the most benefit and what can be trained only out in the field. Understanding of the simulation / live cycle exercise cycle will help target specific task and maximize the effectiveness of the overall training package. Furthermore, to allow the simulation / live exercise cycle to be run, a synthetic representation of the training range is also required. Currently, such representations exist for Ft. Hood and the NTC. As the system is fielded to other units, the number and location of databases will need to increase.

The focal point of the system is the communication between the systems, some of which are operational. This physical connectivity has traditionally been achieved by deploying the communications platoon and laying new wire. The Fixed Tactical Internet, demonstrated at Fort Hood in November 1998 and March 1999, is designed to put a stop to this practice by constructing a communications infrastructure that meets the needs of the simulation and operational communities. By not having to reconstitute the infrastructure, significant cost savings can be realized.

6. Computer Generated Forces Analysis

This section describes and examines the role computer generated forces may play in support of a DBST exercise. A confederation of SAF's, to include OTB, and CCTT could serve as the basis for simulation support for DCX train up. Three cases for these SAF's are explored; (1) OTB as a standalone system (2) CCTT SAF as a standalone system and (3) a combination of the two. The OTB and CCTT SAF have each grown from a different set of requirements to reach their particular state.

The OTB is being developed from the existing ModSAF 5.0 simulation. ModSAF was designed specifically as a modular, data-driven architecture whose characteristics are based on years of lessons learned through SAF development legacy. The ModSAF architecture was specifically designed to provide all of the general capabilities needed by any entity level virtual modeling system. The ModSAF architecture was also designed to allow the easy development and integration of models that become part of the ModSAF system. The characteristics of the architecture are that it is a single-process architecture and a layered inverted architecture. That is, lower level models are not necessarily invoked though a top-down sequence of procedure calls but rather register themselves to be called based on the occurrence of particular events. To accomplish this characteristic and its data-driven programming style, the ModSAF architecture makes extensive use of particular C-language constructs, most specifically function pointers. Although the ModSAF architecture was developed with general characteristics of SAF models in mind, no explicit set of models were initially required as part the architecture design. A large and diverse development community has added models into the ModSAF architecture over time. These additions range from models developed to support a specific experiment at a US Army Battle Lab, to detailed mine/countermine models in support of the JCOS ACTD, and the environmental and dynamic terrain models in support of the STOW ACTD. This clearly demonstrates the accessibility and extensibility of the ModSAF architecture design.

CCTT SAF was designed specifically to satisfy the modeling and system requirements for the CCTT system. Since the CCTT SAF design occurred after the initial implementation of ModSAF , the design was re-engineered using the Ada language based on the ModSAF architecture. Therefore, at the high level of design CCTT SAF and ModSAF are very similar. The CCTT SAF architecture was designed specifically to satisfy only CCTT's system requirements and no more because of a very short schedule requirement. Adding risk to this short development schedule was a set of challenging requirements that were not satisfied by either ModSAF or any other legacy SAF at that time. These requirements included a very large set of validated and verified combat instruction sets (CISs), a very large and densely populated terrain database, a set of dynamic environment capabilities (e.g., destructible buildings, smoke, weather effects, etc.), and very stringent performance requirements. All of these factors along with CCTT SAF's special roles within the CCTT system caused the CCTT SAF design to diverge from the ModSAF baseline.

CCTT SAF is not as extensible as ModSAF because it did not need to support as diverse a set of developers. CCTT SAF's architecture is designed as a multiple process and multiple thread architecture where the dead reckoning functionality, the network interface, and Plan View Display are separate processes to take advantage of CCTT's multiprocessor platform. CCTT SAF also shares a significant amount of common code within the CCTT software baseline for scenario initialization, terrain interoperability and system component interoperability. The specific areas where ModSAF and CCTT SAF differ are the behaviors architecture since CCTT's design was driven by a specific set of required CISs rather than a requirement to be a general behavior model development environment. Also because CCTT SAF was designed as a robust production system using Ada, it takes advantage of the language's strong typing and encapsulation practices.

A federation consisting of OTB and CCTT SAF offers the potential for combining the detailed behaviors of CCTT SAF, in particular with the ground vehicle behaviors, with the breath of entities and open software environment offered by OTB.

The selection of the appropriate case to support a DBST exercise is scenario dependent. Each case provides unique capabilities that may be required to support an exercise. The following is a discussion of the current and planned capabilities, scalability, interoperability, DBST supportability, and planned enhancements for each case

6.1 OneSAF TestBed

The OneSAF Testbed is an outgrowth of the Modular Semiautomated Forces (ModSAF) program. In particular, OTB version A, to be release in May 1999, is built on top of ModSAF 5.0. ModSAF historically has been built as a monolithic application with all libraries or modules statically linked together. This approach forces developers to relink the entire application each time a library is changed.

Many systems allow the user to view the full map display while editing. In ModSAF, the map and the editors are combined in one display. Since the map resizes when an editor is selected in ModSAF, users cannot effectively track actions in a scenario during editing operations. This has been voiced as one of the main usability problems associated with ModSAF.

Historically in ModSAF it has been difficult to access data for Verification & Validation (V&V) or debugging purposes without writing custom, usually non-maintained code. Additionally the interface to access this information (the SAF parser) in ModSAF was usually oriented toward developers, not users. Finally, the data that was available was not aggregate scenario information (e.g., number of entities with mobility kills, the number of blue entities). These deficiencies have prevented ModSAF from being used more prevalently in the analysis community.

One of the strengths of the SAF is its portability to a variety of hardware/OS platforms. The existing SAF runs on SGIs, Suns, PCs, and DEC Alphas. Because the Objective OneSAF will replace the CCTT SAF which runs under IBM's AIX operating system, the OTB SAF should also run on this platform.

This interim OneSAF Testbed is expected to satisfy the following requirements:

- Must replace ModSAF with no decrease in existing functionality and capability,
- Must replace CCTT SAF internally in the CCTT system with no decrease in existing functionality and capability,
- Must be capable of providing battalion level behavior APIs which can be used by the three Domains to further develop battalion and above level behaviors,
- Must be hardware platform independent with the priority on existing CCTT SAF and ModSAF platforms,
- Must provide internal DIS/HLA interface (with respect to SAF Systems only),
- Ease migration to a new, next-generation OneSAF Architecture, and
- Must support the ability to add new equipment, units, behaviors, physical models, editors, and synthetic environment representations.

6.1.1 System Description

The following is a description of the current ModSAF 5.0 system which will serve as the basis for OTB version A. Architectural changes will occur in OTB as it brings CCTT SAF in alignment. These architectural changes are still in development and will emerge over the development of OTB Versions A and B culminating with the release of OTB 1.0 in August 2000. Version A did not contain significant architectural changes from the ModSAF baseline. Therefore, this discussion will refer to the systems interchangeably.

Figure 2 shows the ModSAF/OTB system. ModSAF is composed of two main executables that can be distributed in many ways. The first main executable is the SAF Station. SAF Stations are the human interface to the ModSAF system. The second main executable is the SAF Sims. The SAF Sims provide the modeling capabilities for the ModSAF entities and organizations. SAF Sims and SAF Stations communicate with each other through the use of the Persistent Object (PO) database. This is a distributed database that uses the PO Protocol (POP) to maintain the distributed database. In addition, ModSAF uses the DIS protocol or the SIMNET protocol to communicate synthetic environment physical information. The PO database communicates information between the models that is not represented in DIS or SIMNET. The PO provides command and control information for the simulation of organizations (DIS and SIMNET are oriented to the physical world). Additional executables are noted below.

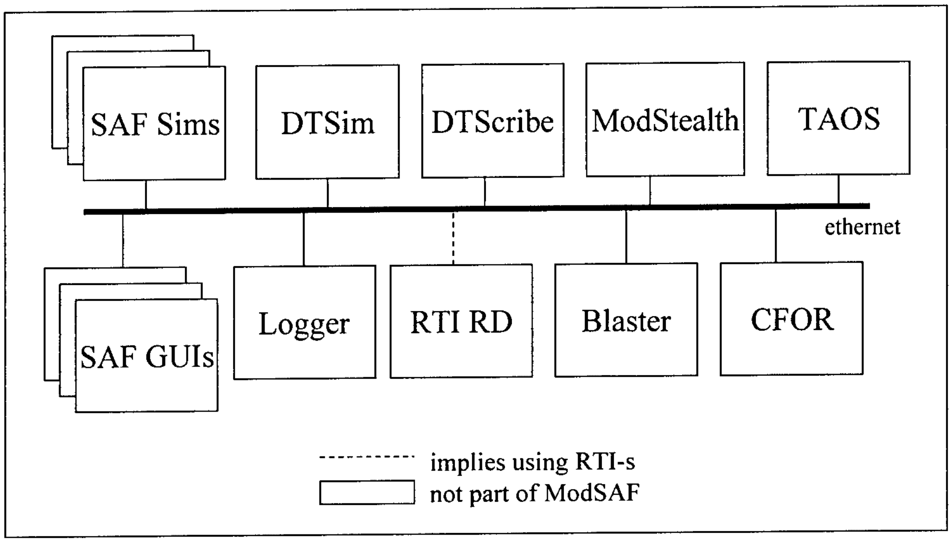


Figure 2: ModSAF/OTB System Diagram

6.1.2 Software Architecture

ModSAF is a single-process architecture. It makes extensive use of function pointers to provide a variety of capabilities as shown below.

- Callbacks – Callbacks provide ModSAF with a registration structure for assigning handlers for a variety of purposes.
- Inverted architecture – ModSAF uses callbacks to invert the architecture. This provides a mechanism for models to register their functions for various purposes such as ticking and event handling.
- Developer defined named events - A developer may create a symbolic name for an event, define when an event is triggered, and support registration of handlers for these events.
- Scheduler – Periodic and one-shot appointments are implemented as function pointers to tick handlers.
- Key technique for extensibility – ModSAF uses the registration capability and the inverted architecture to minimize affected code for new unit or model additions to the system.

ModSAF has callbacks and data driven techniques as the basis for its architecture. This is used in the Graphical User Interface design, entity configuration, network protocols, and behavioral combinations (taskframes).

6.1.3 Software Structure

ModSAF is a flat hierarchy of about 560 C software libraries. Each library contains (or may contain) a makefile, header files, C source files, data files, GUI resource files, and TeXInfo library documentation. There is a small set (about 10) of source directories containing the main program. In addition to the SAF Sim and SAF GUI, the following main programs are part of the ModSAF 5.0 baseline.

- DTSim – Dynamic Terrain Simulator: Simulates the dynamic terrain protocol and standards for ModSAF.
- DTScribe – Dynamic Terrain Scribe: Provides persistence, serialization, and distribution of dynamic terrain information.
- Logger – The Logger provides the capability to log DIS or POP PDUs for later analysis or broadcast.
- RTI RD – The RTI Reliable Distributor implements TCP/IP-based reliable communications for the RTI version s.
- Blaster – The Blaster provides the capability to broadcast large amounts of entity state PDUs for network loading testing. A very simple movement model is used for the entities. No cognitive behaviors or response to detonation events are in the current version of the Blaster.
- ModStealth, TAOS, and CFOR represent executables that are not part of ModSAF but the baseline provides interface support for these executables.

6.1.4 Scalability

Scalability is a key issue for a SAFs ability to support a DBST exercise. Scalability is defined as how well a solution to a problem will work when the size of the problem increases. Many issues can effect how well a solution scales. The value of a simulation such as Janus is in the ability to place a large number of entities onto the battlefield. Janus, in support of FSST exercises, has demonstrated the ability to place in the vicinity of 9999 entities onto a battlefield. By reducing the update rate for the systems to 2 minute intervals, these entities are able to exist in the battle space with no intelligence but an ability to take damage. For a Fires scenario with little or no maneuver, this meets the requirement. However, for a DBST level III – V exercise focused on the ground maneuver element, a more intelligent entity based system is necessary to provide cost efficient C4I interactions necessary to adequately train the commander and staff.

Processor speed and bandwidth continue to be the limiting factors impacting scalability – as processors continue to improve (Moore's Law indicates processor speed will double every 18 months) a SAF will be able to provide more entities for the battlefield. Total capacity and performance benchmarks are difficult to provide for a SAF Capacity and performance are functions of scenario and terrain complexity. ModSAF requires a processor with a minimum of 128 Mbytes of RAM with 256 Mbytes recommended for performance. ModSAF performance numbers are divided into two groups. The first group is a stand-alone capability with no remote entities or network interactions. The second group is in a network environment with 800 external entities (provided by an external program). This provides information on the interaction across DIS and does not include C2 interactions. For the stand-alone version, a 300 MHz Pentium II supports 200 vehicle simulations while a 195 MHz SGI R10000 supports 112. For the network version, the Pentium supports 132 entities while the SGI supports 80.

ModSAF currently partitions the PO Database into groups of 8 maximum participants due to scalability concerns. Each partition is initialized independently and does not share C2 information.

ModSAF user workload was measured during certain Ft. Knox D-site experiments to be on average 40 entities per operator. There was a high variance depending on the side or activity of the entities. During the DARPA Synthetic Theater of War (STOW-97) project, ModSAF averaged up to 100 entities per operator.

Scaling to large exercises is possible but requires managing the behaviors for entities. To achieve 9000 entities in a SAF simulation today with a full set of behaviors would require extensive network management and a large number of operators. Based on a requirement of one operator per 100 entities with full behaviors, to support 9000 entities would require upwards of 90 operators. This is cost prohibitive for a DBST exercise and is therefore unacceptable. Scenario design coupled with exercise management of behaviors provides the potential to achieve large numbers of entities.

Recent work at Fort Knox indicates the ability to provide a large number of SAF entities for an exercise can be achieved as demonstrated in the SimEx. This exercise made use of ModSAF 4.0, DIS2.03 with approximately 2000 simulated vehicles total. Workstations included 400Mhz Solaris X86, Sun Ultra2, Sun Ultra1, and SGI R1000 and R4400 all having 256 Mb RAM. SAF machines were in pocket mode except for the SGI R4400, and each workstation averaged less than 100 vehicles. The network was 10BaseT, with machines plugged directly into a PowerHub7000. The most significant change made to the baseline to reach this performance level was to reduce the network traffic. First, all ModSAF radios except for the artillery radios were disabled, and the Transmitter heartbeat was reduced to 60 seconds. Second, no ModSAF vehicle was allowed to transmit Entity_State PDUs more frequently than every 3 seconds. Finally, the minefield PDUs were modified so that fewer mines were described. Network traffic rate was ~600 PDUs per second, and did not vary significantly when vehicles moved. The construction of the exercise resulted in the controller's ability to handle considerably more entities than the normal 1:100 ratio. As more entries are used solely for indirect fire targets , supporting and adjacent forces, and ground clutter, the ration should continue to climb.

Following the SimEx several additional techniques were experimented with to improve performance to reach ~5000 vehicles. The initial approach was to partition the network so that each workstation would only see part of the traffic. This was difficult to accomplish and manage. Another approach involved reducing the network traffic using "super" Entity_State PDUs, each describing several vehicles. This also did had limited success. Another approach involved reducing the tick rate for "distant" vehicles which met with little success. Finally, each workstation was partitioned to only pay attention to part of the battlefield, even while PDUs for every vehicle were on the network resulting in a dramatic effect on the network. ModSAF's performance is affected more by the total number of vehicles it has on its list (vtab_vehicle_table) than by the total amount of network traffic. For this approach, here called Area of Interest (AOI), the battlefield was divided into a grid of arbitrary size. Whenever a Entity_State or Aggregate_State PDU was about to be sent, the vehicle (or unit) location was converted into a grid x,y. The grid x & y were stored in padding fields of the PDU and it was then transmitted as usual. Each ModSAF maintained a grid that described where its local vehicles were. When each local vehicle was ticked, that vehicle's grid cell was marked as "used". Periodically, cells without current vehicles were marked as "unused", and then each area of "used" cells was extended by a fixed amount, such as 10km. At this point, the AOI grid shows the complete area of interest for all local vehicles. Then, as each incoming Entity_State or Aggregate_State PDU is received, the stored grid location is retrieved and compared with the AOI grid. (This evaluation is performed without decoding the PDU, and no floats are involved.) If the vehicle described by the PDU is a "used" AOI, the PDU is immediately discarded. That vehicle will not appear on the vtab_vehicle_table. The result was surprisingly effective. Approximately, 4500 vehicles were generated with an average of~1200 PDUs/sec. A workstation was loaded with a typical force of ~100 vehicles. The AOI would then typically turn on ~2000 vehicles. The high network rate wasn't a problem. If a vehicle was placed in a new area, the AOI would turn on vehicles in that area. As the machine's force moved, the AOI automatically moved along with it. Even scattering the vehicles worked, since each only saw a small part of the battlefield, so the total number of vehicles turned by the AOI was relatively small.

This AOI model assumes that while there are lots of vehicles in the world, each workstation only needs to know about a manageable number of the total. It requires no configuration, and each machine can define its own buffer size (and change it as desired). This method could be used for much larger exercises as well. A set of machines supporting a region could be protected by a gateway, and since the examination of individual PDUs is so simple, the gateway shouldn't have much trouble.

The Blaster, as depicted in Figure 2, also provides the ability to achieve high entity counts for SAF. The blaster is typically used to provide large amounts of entities for network testing. Currently when the blaster is on, the entities created have little or no intelligence. However, there is a tradeoff for achieving these levels of entities – the SAF often is “dummied” down. Scenario development plays a key role, focusing on the areas of interest and modifying the behaviors of the entities can provide a high entity count while achieving the level of SAF intelligence necessary to support a DBST exercise.

A composable behaviors technique also offers potential to addressing scalability. Composable behaviors will be part of the OTB in build A for Rotary Wing Aircraft. Currently Composable Behavior Technology (CBT) is a research project that has initially focused on aviation behaviors as a proof of principle. This technique allows the operator to create complex behaviors from a set of primitive behaviors. This will allow for creation of entities outside the main area of interest with a limited set of behaviors thus reducing processing and bandwidth requirements.

Scalability in OTB can be achieved through these load management techniques in combination with scenario design. There will continue to be tradeoffs between SAF capability and entity count.

6.1.5 DBST Supportability

The ability for OneSAF Testbed to support a DBST exercise remains scenario dependent. Figure 3 depicts a conceptual layout of the connectivity between the C4I systems and the ground simulation driver (OTB).

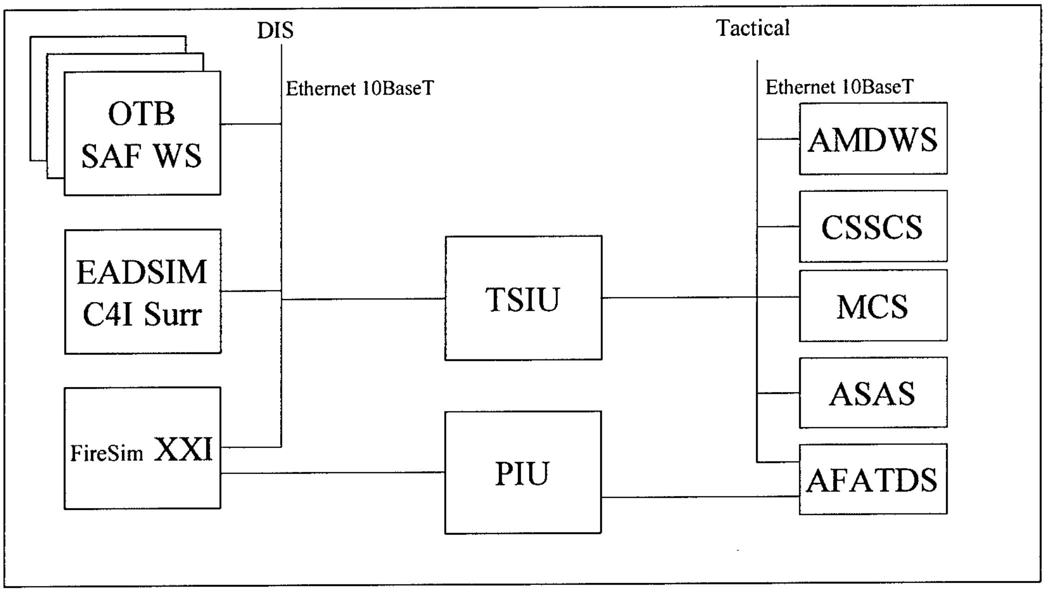


Figure 3 OTB DBST Conceptual Model

FireSim XXI would generate the fires support activity for the exercise and provide tactical messaging to the AFATDS via the PIU. The requirement for large numbers of entities is primarily to support a DIVARTY exercise. The OTB would provide the ground maneuver (expect 200 entities for a battalion combat team exercise; 800 entities for a brigade exercise) picture and could, through the use of Area of Interest techniques, provide the large numbers of entities for the fires exercise. The TSIU would provide the ability to generate tactical messages as well as routing the messages to their appropriate C4I device. The TSIU currently requires specific signal PDUs to generate C2 messages. These signal PDUs are typically generated by EADSIM or the C4I surrogate. OTB currently does not provide these signal PDUs but could be easily modified. A data logger may be utilized to capture the simulation traffic for use in AAR and potential use for a STAFF COFT.

Scalability as it relates to an individual exercise will be driven by the scenario. For the DBST requirement of not to exceed 6 operators, in a "standard" scenario operating on a Pentium 400Mhz PC, up to 1200 entities can be expected. The ability of an operator to control 200 entities also is dependent on complexity of the exercise.

6.2 OTB SAF Programmed C4I Upgrades

The OTB program will be developing a C4I messaging capability initially focused on the messaging in the lower tactical internet. A new C4I Digital Messaging Interface (DMI) will be incorporated into the OneSAF Testbed Baseline. The interface will provide for message processing by sending and receiving digital messages at the appropriate time with the appropriate data. The interface will insulate the SAF behavior libraries from digital message processing completely. The behavior libraries will register with the interface with pertinent behavior data, and the interface will be responsible for the generation of messages and when to send them. When receiving messages, the interface will notify the behavior libraries of significant events via callbacks. The C4I Interface will maintain digital message types, message formats, and processing requirements via configuration files to minimize the effects of message modifications on the C4I Interface implementation.

An OTB SAF DMI will be implemented in order to support the current and future requirements for C4I and digital messaging. This core interface will be in place for Build B and its capabilities will be demonstrated in an interoperability demonstration with the Closed Combat Tactical Trainer (CCTT) SAF, as depicted in Figure 4. The demonstration will consist of sending and receiving (reacting to FBCB2 Variable Message Format (VMF) messages.

The Tactical Simulation Interface Unit (TSIU) will be utilized to process the OTB SAF Signal Protocol Data Units (PDUs) containing the VMF messages. The TSIU was selected for two main reasons: 1) it provides two-way communications, and 2) it processes Signal PDUs. The OTB SAF currently uses Signal PDUs for radio and Longbow IDM communications. For Build B, the C4I digital message processing will continue to utilize the Signal PDUs. This implementation may be updated in future releases.

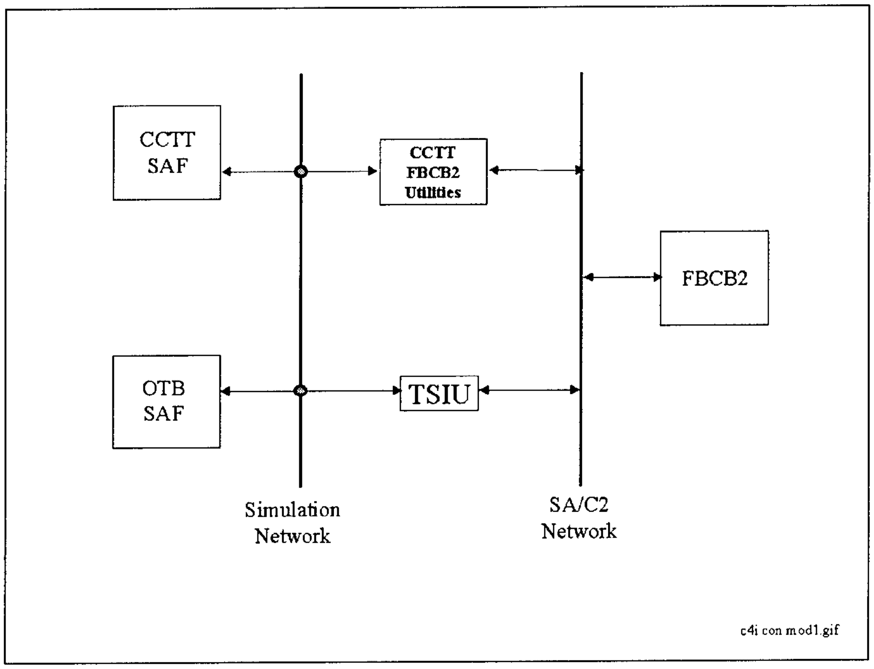


Figure 4 C4I Digital Message Interface Conceptual Model

Figure 5 provides a more detailed view of the DMI architecture. The DMI will utilize the network communication libraries currently implemented in the OTB SAF. The two main parts of the DMI are the Digital Message Manager (DMM) and the Digital Data Manager (DDM).

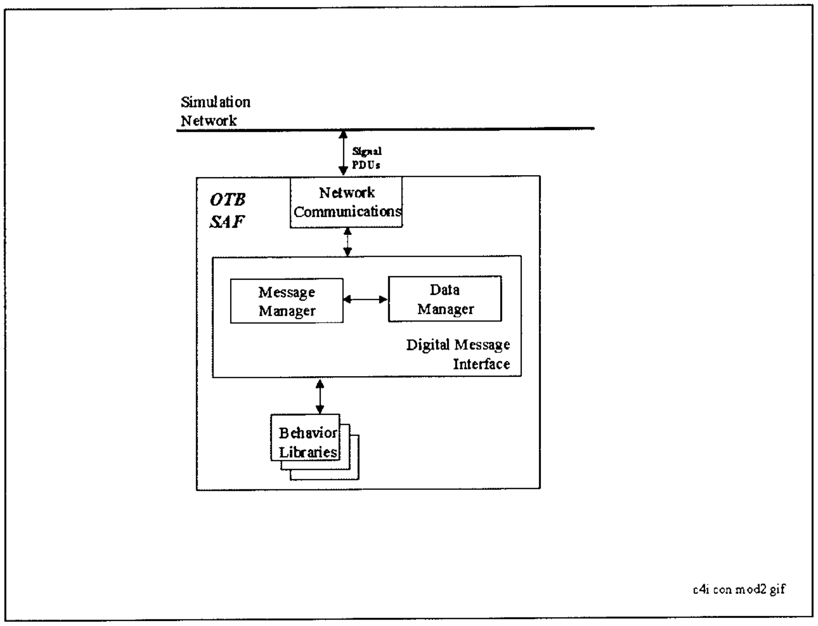


Figure 5 C4I Digital Message Interface Architecture

The DMM interfaces directly with the OTB SAF network communications library in order to process incoming and outgoing digital messages, as depicted in Figure 6. The DMM utilizes configuration files that describe the message type formats (e.g., VMF), therefore if a message format changes it will not affect the DMM implementation. The DMM maps the message format described in the configuration file with the message data provided by the DDM.

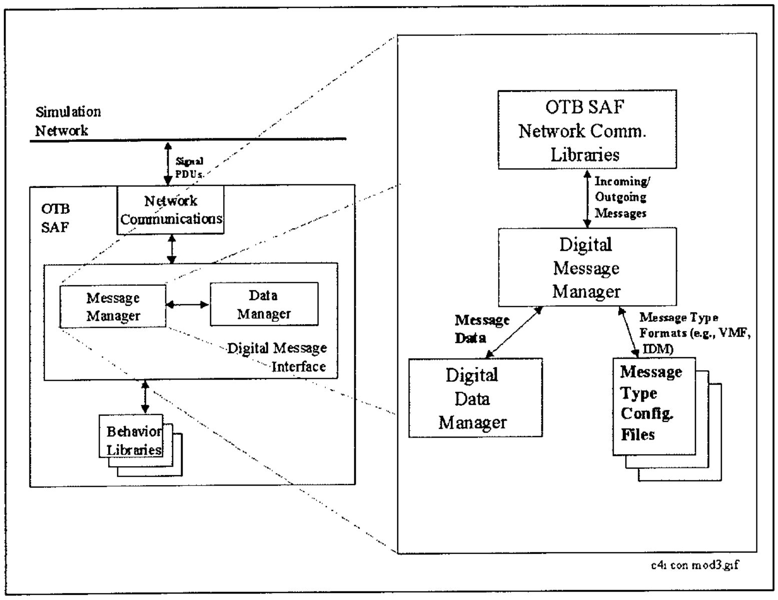


Figure 6 Digital Message Manager Conceptual Model

The DDM, as depicted in Figure 7 interfaces with the DMM as described above. The DDM interfaces with the behavior libraries by providing a mechanism for the libraries to register their pertinent data for outgoing messages, and register for callbacks for significant event information in incoming messages.

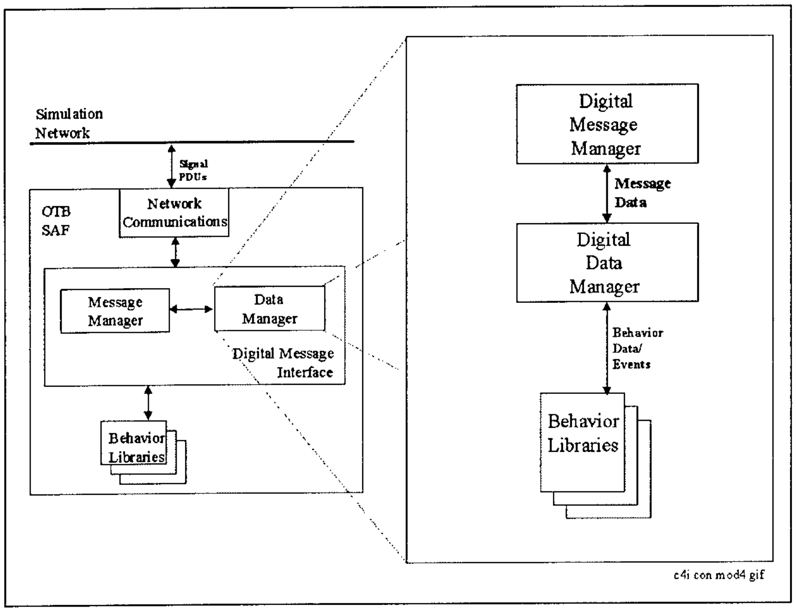


Figure 7 Digital Data Manager Conceptual Model

OTB SAF will also be capable of a behavioral response to a limited set of C4I messages. These messages are currently being identified but will predominantly focus on FBCB2 VMF messages. This will allow the SAF to respond to C4I directions such as a call for fire or a specific FRAGO. The current focus of the OTB C4I effort will be at the individual entity messaging predominantly at the FBCB2 level. This will not directly support Battalion and Brigade level DBST training but could serve as the basis for a bottoms up feed of situational awareness and C2 messaging.

6.3 CCTT SAF

CCTT SAF is part of the overall CCTT system that includes the CCTT manned modules and additional workstations. Recently, CCTT SAF has been decoupled from the CCTT system to a standalone version. This version essentially offers all the functionality of the CCTT SAF while providing the flexibility of not requiring connectivity with the manned modules for operation. The CCTT Standalone SAF operates on a Motorola duel processor AIX machine.

6.3.1 System Description

Figure 8 shows the runtime distribution structure for CCTT. CCTT has many similarities to the ModSAF structure.

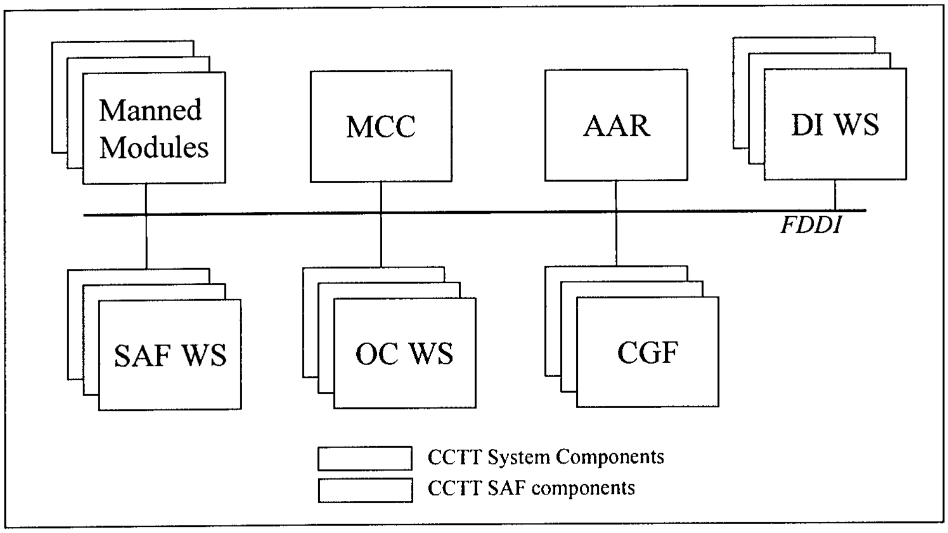


Figure 8: CCTT SAF System Diagram

For CCTT, the SAF WS and OC WS are equivalent to the SAF GUI and provide the human interface for the SAF operator and the OC trainee respectively. The CGF corresponds to the ModSAF SAF Sim. The CCTT system consists of other executables such as the Manned Modules (crew cabin simulations), MCC (master control), AAR (after action review), and the DI WS (dismounted infantry trainee station). CCTT uses DIS to communicate information about the synthetic environment (once again a description of the physical characteristics of that world). CCTT SAF uses the SAF Entity Object Database (SEOD) as a distributed object database for communication between the workstations and the CGF simulators. The SEOD uses the CGF Protocol to communicate data changes and events for command and control information. One point of comparison between the ModSAF diagram and the CCTT diagram is that CCTT SAF exists as a integral sub-component of a larger system.

A CCTT SAF platform is an IBM or Motorola AIX computer system and costs approximately $8K.

CCTT is a multi-process architecture. CCTT SAF makes use of multi-process threading to allow for execution of models on the symmetric multi-processing platform used by CCTT. CCTT was written in Ada 83, but makes limited use of function pointers. These are used to implement a callback structure similar to ModSAF. This callback structure is used to allow for registration of event handlers (predefined events) and scheduler appointments (periodic and one-shot). The CCTT SAF architecture is data driven as well but not to the extent of ModSAF.

6.3.2 Software Structure

The CCTT SAF software library organization mirrors its design decomposition. It is divided into directories and subsystems (a Rational Apex concept). Subsystems contain the Ada packages (specifications and bodies). CCTT relied on the integrated development environment (IDE) of Apex to build the executables and did not use makefiles. The execution environment contains all the data files and GUI User Interface Language (UIL) files necessary for the execution of CCTT SAF. These are organized along the system architectural types (i.e., the system applications such as the SAF Workstation and the CGF). In CCTT SAF, there is no equivalent documentation to the ModSAF TeXInfo files.

6.3.3 Scalability

CCTT SAF was designed specifically to support company lanes in a battalion size scenario. The SAF is not scalable to large numbers of entities – the blaster and area of interest techniques which apply to OTB are not possible to implement within CCTT without major rearchititecting. A typical entity count for CCTT SAF per machine is 120. CCTT SAF can easily support a battalion combat team size exercise of 200 entities.

6.3.4 DBST Supportability

The ability for CCTT SAF to support a DBST exercise remains scenario dependent. CCTT SAF as a standalone can support battalion and brigade level ground exercises. A bridge would be required to provide network management and FDDI to ethernet connectivity.

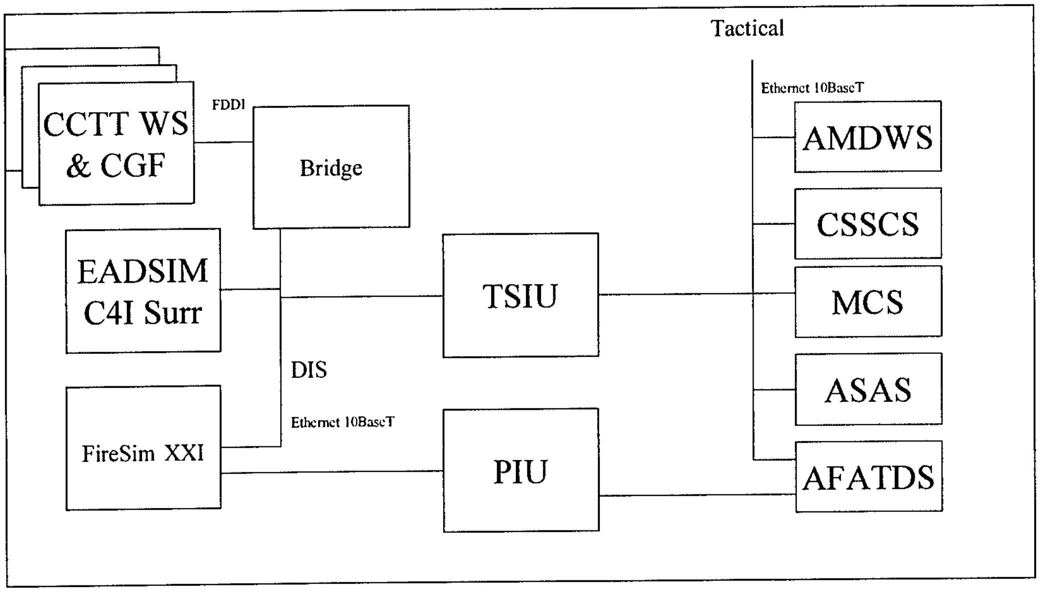


Figure 9 CCTT SAF DBST Conceptual Model

6.4 CCTT Programmed C4I Upgrades

The CCTT program has recently modified the manned modules to accept FBCB2 hardware and support situational awareness and digital C2 messaging. The actual FBCB2 hardware has been integrated into the manned modules and the CCTT SAF has been modified to respond to digital messaging. CCTT SAF has been modified to provide Situational Awareness information and C2 messaging to the FBCB2.

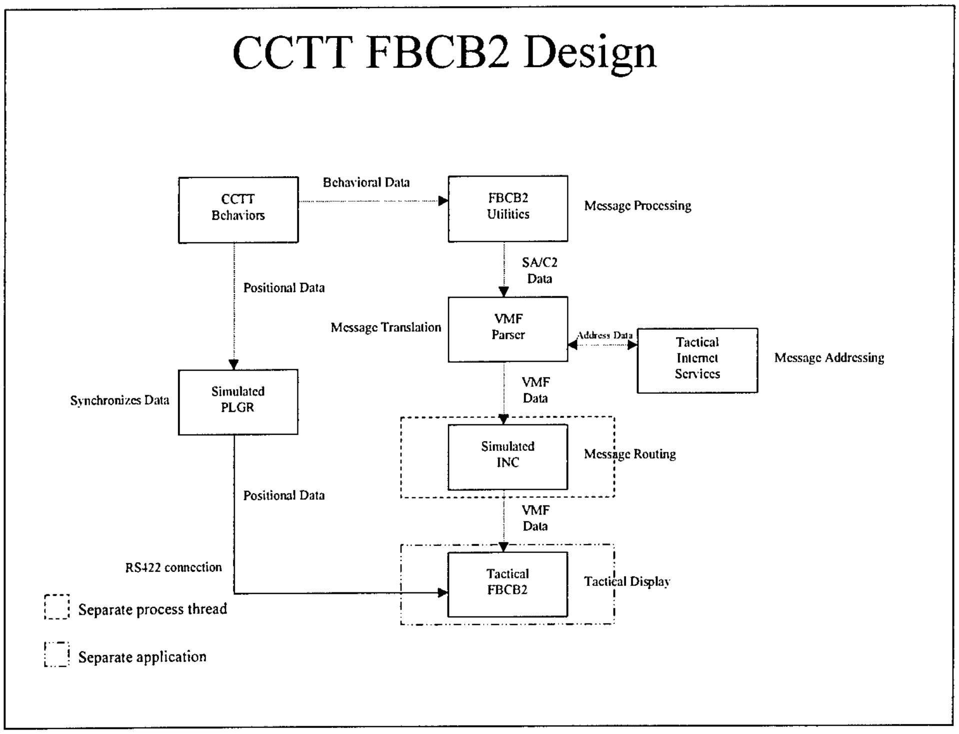


Figure 10 CCTT FBCB2 Architecture

FBCB2 messages originate from current CCTT CGF behaviors. The tactical situation is the deciding factor determining the type of message which will be sent. FBCB2 utilities is called when certain tactical situations are present that require a VMF formatted message being sent. FBCB2 utilities is responsible for furnishing the appropriate data associated with each VMF message. This new situational awareness or command and control data is then sent to the VMF parser to be translated into the correct format. Concurrently, CGF positional data is sent to the tactical FBCB2 workstation via an RS422 connection. Once the VMF parser receives SA or C2 data, it uses tactical internet services to retrieve the correct message addresses as defined by the current Force XXI organizational structure. Once the VMF parser has the message addresses from internet services, it encapsulates the VMF message and sends it to the simulated INC (internet controller). The INC is responsible for routing the message to the appropriate simulated equipped vehicle or manned module.

Phase III, completed earlier this year, of this upgrade has provided a capability for the CCTT SAF to generate the following messages in Table 2

Send	Receive
Threat Warning	Call for Fire
Situation Report	Message to Observer
Message to Observer report	End of mission/Surveillance
Spot Report	Obstacle Report
Position report	

Table 2 Phase III CCTT SAF Messages

Phase IV of the FBCB2 upgrade, scheduled for completion in October 1999 provides the following FBCB2 messaging capability in the CCTT SAF

Send	Receive
Call for Fire	Observer Status
Subsequent Adjust	Bridge Report
Check Fire	Logistics Report
On Call Fire Command	Bridge Report
End of Mission / Surveillance	Observer Notification
Obstacle Report	Spot/Salute Report
Strike Warning	Threat Warning
Logistics Report	Strike Warning
Observer Status	Situation Report
Mine Laying Report	Mine Laying Report
Airborne Fire Mission	Airborne Fire Mission
Personnel Status	Personnel Status
Observer Notification	Subsequent Adjust

Table 3 Phase IV CCTT SAF Messages

6.5 CCTT/OTB Federation

6.5.1 System Description

Federating CCTT Standalone with an OTB SAF could provide the DBST with a solution for achieving large entities counts while maintaining the detailed behaviors required for SAF in a DBST exercise. In order to federate CCTT SAF with OTB, several issues must be addressed including network communications, DIS standards, broadcast versus multicast schemes, terrain interoperability, and "fair fight". There are numerous approaches with hardware and software to solve these problems. Hardware solutions are often a one time expense (example is buying a power hub) that usually do not grow with a solution over time. Software solutions typically evolve over time and allow the system to grow.

The network issues focus on the Fiber Distributed Data Interface (FDDI) and ethernet differences as well as the broadcast versus multicast issue. CCTT makes use of a Fiber FDDI as its network architecture using a multicast addressing scheme. OTB uses an ethernet architecture, typically 10baseT, with a broadcast addressing scheme. Multicast addressing sends packets to specific machines on a network. Broadcast, which is a subset of multicast, sends packets over ethernet that all machines are willing to accept. The advantage of multicast is that only those machines subscribed to a particular set of groups receive the packets sent to the those selected groups thereby, filtering out the unneeded packets and reducing the processing requirements. CCTT SAF can be placed in the broadcast mode with minimal degradation as the CCTT SAF typically receives all network traffic. The CCTT manned modules may experience some performance degradation as manned modules make use of an Area of Interest scheme and in the broadcast mode, the modules receive all traffic. For a SAF only federation in DBST, this should not be an issue.

To enable communications between CCTT SAF and OTB, a bridge, which is a device that forwards traffic between network segments based on data link layer information, can be developed. The bridge would support protocol exchanges between the DIS 2.04 and 2.04R standards and would be hosted on a system with both an ethernet port and an FDDI port. Figure 11 depicts the functionality offered by a bridge. This Bridge could also enable multicast to broadcast as demonstrated by the use of the Naval Postgraduate School Dis Bridge used during the NSC CCTT SAF ModSAF Interoperability Study February 1999. Us of this approach will negate the need to modify the multicast scheme within CCTT. The CCTT side of the bridge would have to subscribe to all groups to ensure it receives all the packets on the net. The Bridge would also enable terrain interoperability through ground clamping (to be discussed in interoperability section).

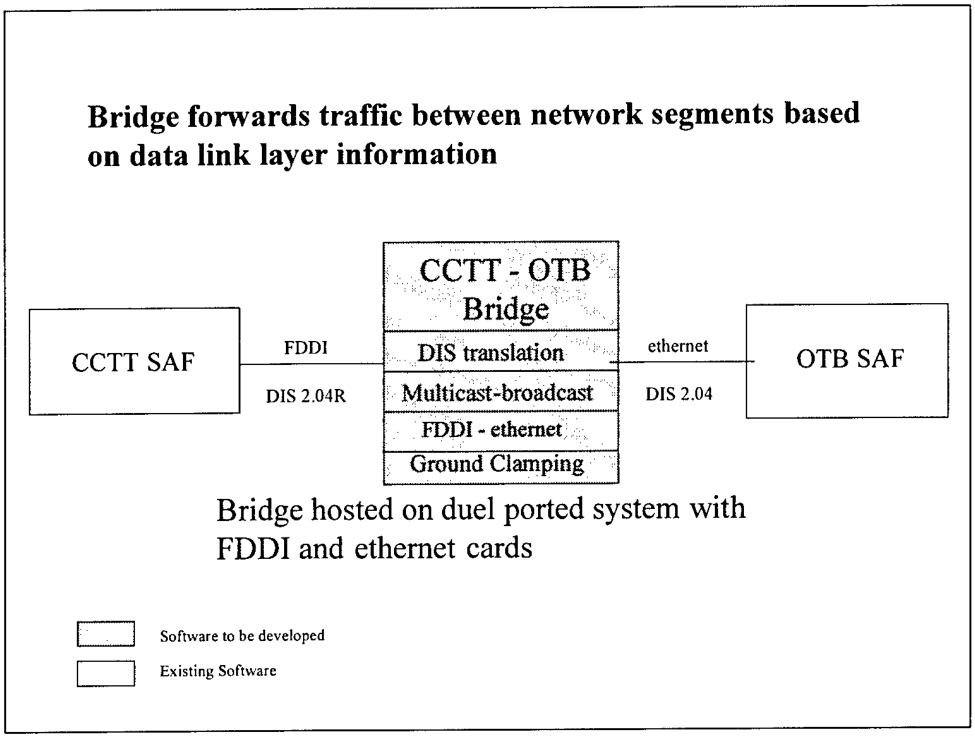


Figure 11 CCTT - OTB Bridge

6.5.2 Scalability

Scaling of the CCTT/OTB Federation will be scenario dependent. The combination of behaviors that this federation can provide offer a great potential to an exercise but must be properly managed during an exercise. Figure 12 depicts a potential grid approach for a scenario that can provide the entity count desired for a large entity exercise while also providing the detailed behaviors needed for a ground maneuver exercise. The size of each grid would be scenario dependent but we would anticipate the CCTT SAF supporting a battalion combat team of approximately 200 entities (red and blue) with potentially supporting a brigade ground exercise of 800 entities. The center grid would be the primary area of interest for the ground maneuver unit (typically a battalion or brigade unit). While the figure shows the grids of roughly equal size, this is not a requirement and, in actuality, very seldom happens. The scenario will dictate the location and composition of the ground maneuver force. In some case they might not be represented at all, or a lower fidelity representation can be used. If this is the case, CCTT SAF need not be part of the exercise.

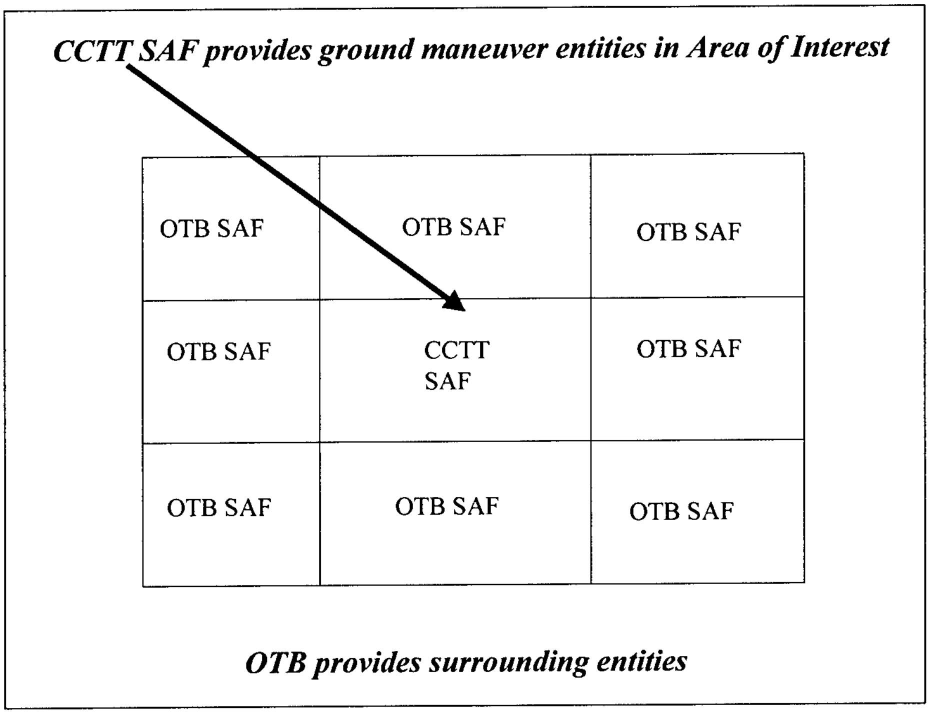


Figure 12 Notional OTB/CCTT Federation Conceptual Grid

The strength of the CCTT SAF is the validated behaviors for ground maneuver exercises. These behaviors are focused at the platoon and company level. The grid approach allows for the DBST exercise to take advantage of these behaviors. OTB SAF, making use of the area of interest methodology, could provide the surrounding units and achieve the large number of entities required. The CCTT SAF would provide the all ground interactions for the maneuver unit while OTB would provide the surrounding entities to support the fires and intelligence picture. The primary obstacles to overcome on the interactions on the boundaries of the CCTT SAF with the OTB SAF. Interoperability issues between the SAFs will be addressed below.

Figure 13 CCTT SAF/OTB depicts the architectural layout for a battalion combat team exercise with a surrounding DIVARTY exercise. To provide a battalion combat team of CCTT SAF would require 4 CGF machines and 2 workstations, all Motorola AIX duel processor machines. To provide the supporting entities in OTB SAF would require 4 Pentium 450 Mhz machines operating with a blaster or area of interest scheme. The bridge would be hosted on a duel FDDI ethernet card Sun Ultra workstation providing the network management for the system.

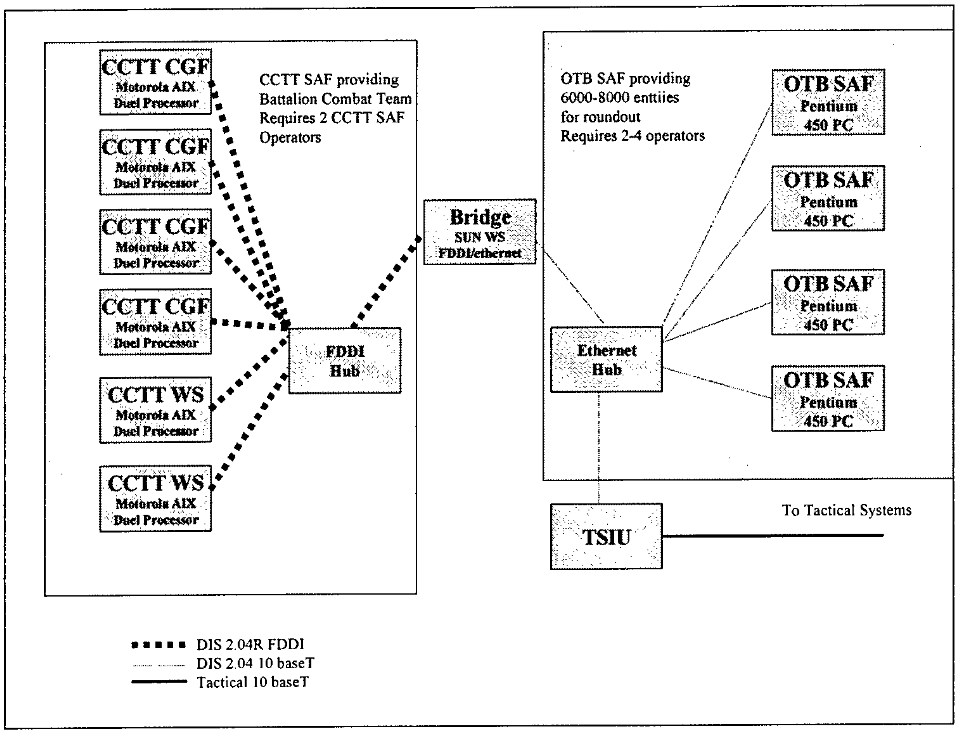


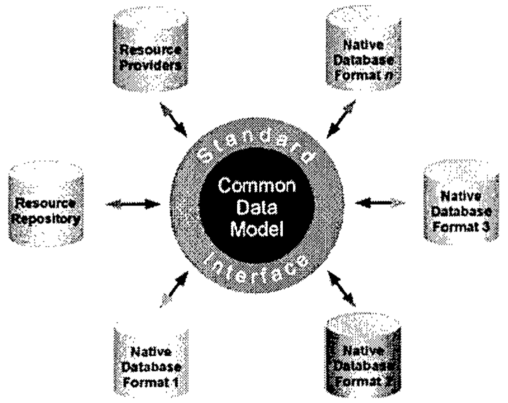
Figure 13 CCTT SAF/OTB

6.5.3 Interoperability

Interoperability refers to the ability of software and hardware on multiple machines from multiple vendors to communicate. The primary interoperability issue for CCTT and OTB SAF is in sharing of a common synthetic natural environment (SNE). The SNE represents the passive/non-sentient parts of the simulation, including terrain/features, ocean and weather. SNE provides services to support behavioral models in reasoning/planning and physical models in correctly responding to ground truth. Sharing of a common SNE is essential for issues of a fair fight and quality training. In the short run, scenario design can address the lack of a common SNE by preventing, or at least limiting, interactions across simulations. However, in order to provide a robust DBST simulation environment which allows for interaction among entities and in particular if the manned modules are introduced into the exercise interoperability must be addressed.

OTB/ModSAF makes use of the compact terrain database structure (CTDB) which provides the user with a decentralized, open interface providing a great deal of flexibility. There are numerous terrain database sources that ModSAF can convert from including S1000, EaSiest, and Multigen through the use of a compiler. CCTT makes use of the model reference Terrain Database (MrTDB) which is a much more structured architecture. CCTT compilers presently can use only a CCTT-specific format known as SIF++. These different terrain database formats are again the results of differing program requirements. These databases differ in their approach to feature representation, physical features, dynamic terrain, environment, man-made effects, and SNE reasoning.

The long term solution to the terrain interoperability problem between CCTT and OneSAF Testbed will be the development of the Synthetic Environments Data, Representation and Interchange Specification (SEDRIS) program. SEDRIS is a Defense Modeling and Simulation Office (DMSO) program with engineering and management support provided by STRICOM. The SEDRIS project was conceived and implemented to capture and provide a complete (terrain, ocean, atmosphere, and space) data model of the physical environment, access methods to that data model, and an associated interchange format.



Databases are converted from a specific format into a standard SEDRIS format. Individual programs develop a SEDRIS reader to accept SEDRIS format.

Figure 14 SEDRIS Conceptual Model

These SEDRIS developed mechanisms facilitate interoperability among heterogeneous simulations by providing complete and unambiguous interchange of environmental data. The range of M&S applications addressed in the SEDRIS development includes training, analysis, and system acquisition and supports visual, computer generated forces, and sensor perspectives. Additionally, SEDRIS provides a standard interface for geographic information systems, which are key components in the generation of complex integrated databases for simulation applications. The data interchange specification supports the pre-runtime distribution of source data, three-dimensional models, and integrated databases that describe the physical environment for both simulation and operational use.

Figure 14 depicts the SEDRIS approach to creating a common data model. The intent of the development is to create one standard method to interchange environmental databases in a consistent fashion across the widest possible range of heterogeneous simulation systems that incorporate synthetic environments. The interchange specification consists of the interchange format, rules for generating compliant transmittals, and the interface description to the data model representation. The data model implementation is transparent to both data providers and data consumers. An API efficiently enables M&S systems and provider conversion software to pass data through the data model. The design of the API and transmittal files does not mandate any specific hardware platform dependency. Use of the data interchange format frees the interchange from any operating system dependencies. Common tools and software are shared and reused, thereby achieving a reduction in conversion and interchange costs. Ad hoc conversions are eliminated. Therefore, there is less opportunity for the loss of significant data leading to correlation problems.

Development of the conversion programs to go from a specific format to a SEDRIS format is on-going. TASC is currently developing a CTDB to SEDRIS compiler. Work on this program continues with anticipated releases coming in late 1999. SAIC is developing a CCTT to SEDRIS compiler with an anticipated delivery of 1 January 2000. These programs should enable the use of P1 (NTC) and P2 (Europe) databases. The OTB is developing a OneSAF front-end SEDRIS reader that will read in databases formatted in SEDRIS to be used with the OneSAF Testbed Baseline. This is being planned as a technology insertion for build B but may be delayed. For long term DBST interoperability issues, SEDRIS should be considered as the solution.

For the short term, ground clamping can be used to solve terrain correlation problems. Ground clamping forces the entity, regardless of the elevation contained in the packet, to be located on the terrain surface. In doing so, ground clamping provides for a means of conversion between the CCTT and OTB coordinate systems. This method has been used in previous interoperability studies. The CCTT modules use geocentric coordinates to determine their positions in the database independent of the terrain. ModSAF also uses geocentric coordinates for vehicle positioning which resulted in a correlation difference between CCTT manned modules and the ModSAF entities. The error in the X and Y axes are typically less than 1 meter and the error in the Z axis was less than 3 meters. The Z axis error is greater due to the geocentric to MGRS coordinate transformations being done by ModSAF and/or CCTT. Failure to correct these errors can result in "flying tanks" and other anomalies. By forcing the entities to follow the surface of the local terrain skin, the errors introduced by the differing coordinate transformations and database representations can be eliminated. Ground clamping would be provided in the bridge program in Figure 11

6.5.4 DBST Supportability

Figure 15 depicts the architecture for a federation of CCTT SAF with OTB to support a DBST ground maneuver and fires exercise. This federation offers the detail of validated CCTT behaviors for ground maneuver and, utilizing the grid approach for scenario laydown, the potential to provide large numbers of entities for the fires exercise exists. It also offers the potential for manned CCTT modules to participate in a DBST exercise.

Development of the bridge will be one key to providing interoperability between the SAFs. The bridge will unite the FDDI with ethernet, address the ground clamping issue, and provide mapping between DIS 2.04 and DIS 2.04R PDUs.

The TSIU will provide the generation of tactical messages for the MCS, ASAS, AMDWS, and CSSCS while the PIU will continue to provide the messaging for AFATDS.

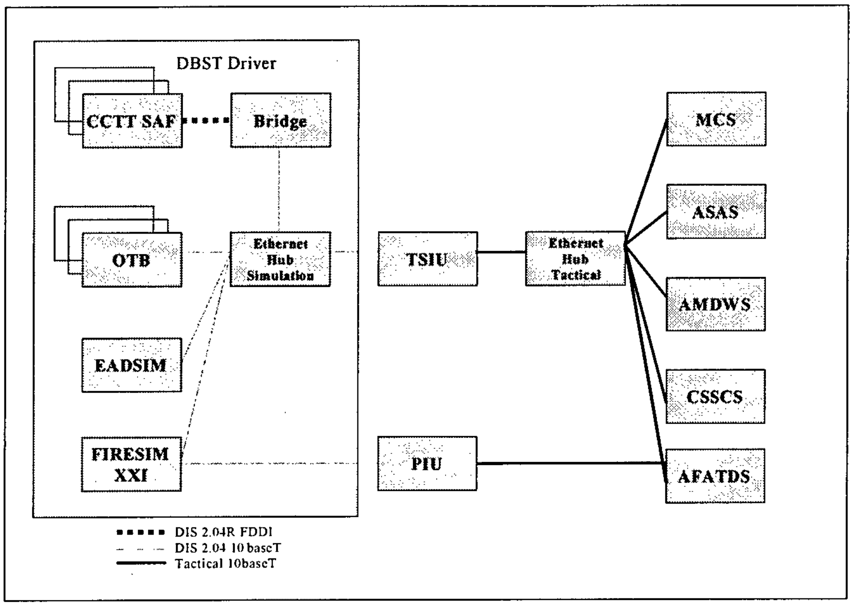


Figure 15 DBST Architecture

This federation could be easily configured for supporting a wide variety of training exercises ranging from a battalion through brigade. The numbers of operators would be training event dependent but a good planning figure would be two CCTT operators per battalion and two to four operators for the surrounding OTB. More complex exercises may require an increase in the number of operators.

6.6 Computer Generated Forces Summary

Table 4 provides a summary of the OTB, CCTT SAF, and federation of CCTT SAF and OTB. Each SAF can provide a the DBST with an entity based simulation capability. The selection of the appropriate SAF for a DBST training event will be scenario dependent. OTB, modified to scale up for large exercises, could support a Fires scenario. CCTT SAF, on its own, could provide the ground maneuver driver for a battalion or brigade level exercise. A federation of OTB with CCTT SAF offers the potential to provide the large numbers of entities required of a Division Fires scenario while providing the detailed behaviors to support a ground maneuver exercise.

	OTB	CCTT SAF	Federation of CCTT SAF/OTB
System Requirements	Operates on DEC Alpha, SGI, SUN, PC. Recommend Pentium 450 PC for DBST LOD. Ethernet network	Operates on IBM or Motorola AIX machine. Requires a CGF and SAF workstation. FDDI network.	Requires a Bridge to address interoperability issues. Bridge could be on a PC with FDDI and ethernet cards
Scalability	Potential exists to scale to large exercises using network management tools and reduction of behaviors outside Area of Interest.	Designed to support company lanes for Battalion Exercises. Can provide up to Bde of ground entities (blue and red)	Grid approach for federation offers large entity count from OTB with validated ground behaviors of CCTT.
Standards	DIS 2.04	DIS 2.04R	Requires a bridge
SNE/Interoperability	Uses CTDB. SEDRIS conversion programs in development	Uses MrTDB SEDRIS conversion programs in development	Ground Clamping for initial terrain interoperability. SEDRIS provides long term solution
Behaviors	Variety of behaviors – generally validated by developer for limited use. Recent improvements in Aviation Behaviors	Validated Ground Maneuver Behaviors	Potential exists for validated CCTT behaviors with breath of OTB behaviors
C4I Messaging Capability	Programmed for FBCB2 VMF messages for OTB Build B	Supports FBCB2 VMF messages	FBCB2 Messaging

Table 4 Computer Generated Forces Capabilities

7. DBST SAF Implementation Approach

7.1 Blueprint/Implementation Plan

Recognizing that this is a very aggressive program, a schedule that attempts to balance the needs to show progress vs. the need to do work is contained in Table 5. Of particular interest is the conduct of three developer tests on one user exercise within the first year. While very demanding, this type of schedule is required to show progress and maintain buy in from the larger community. After the first Simulation Exercise (SIMEX), the developers are give the opportunity to conduct a more rigorous development cycle building what we expect to build a fielded product.

Event	Date	Comment
Digital Capstone Exercise (DCX)	April 01(NTC) September 01(FT Hood)	Notional Exit Criteria
System Baseline and Code Freeze	December 00	
SIMEX2	September 00	Full up, On Site Test
SIMEX1 (Beta Test)	December 99	On-Site Test
Scalability Test	September 99	Network / System loading
Terrain Test (Alpha Test)	August 99	All on same perceived terrain
Connectivity Test	July 99	All systems talking to each other

Table 5. Notional Schedule

While this schedule shows a road map to the planned DCX, there is nothing that prevents the system being used in other experimental programs such as STRIKE FORCE. All that will be required is a harmonization and prioritization of the schedules and requirements.

7.2 SAF Capabilities for DBST

The following details a plan for implementing a federation of CCTT SAF and OTB into the DBST. Near term focuses on the next 6 to 12 months; mid term from 18 to 24 months and long term after 24 months.

7.2.1 Near Term Capability

The initial DBST capability would focus on federating CCTT Standalone SAF with OTB version A focusing on the ability to provide a large entity count to support the Fires scenario and provide the ground maneuver driver for a brigade exercise. This capability would allow the brigade staff to conduct a minimal level III-IV DBST exercise. It is anticipated that this capability would be developed over a 6 to 12 month period. The following plan provides an approach for achieving this capability;

- Bridge – development of the CCTT SAF – OTB bridge to provide network management between FDDI and ethernet; translation between DIS 2.04 and 2.04R; and ground clamping for limited terrain operability.
- Scalability test – develop Area of Interest/Blaster capability for OTB to provide 6000 – 9000 entities with varying levels of behaviors to support a Fires exercise.
- Simulation Systems – integration and test of CCTT SAF – OTB federation with FIRESIM XXI and EADSIM/C4I surrogate.
- C4I Systems Integration – test and integration with the TSIU and ATCCS for connectivity, message creation, and message routing.
- DBST System – final test and evaluation of simulation and C4I systems for selected scenario.

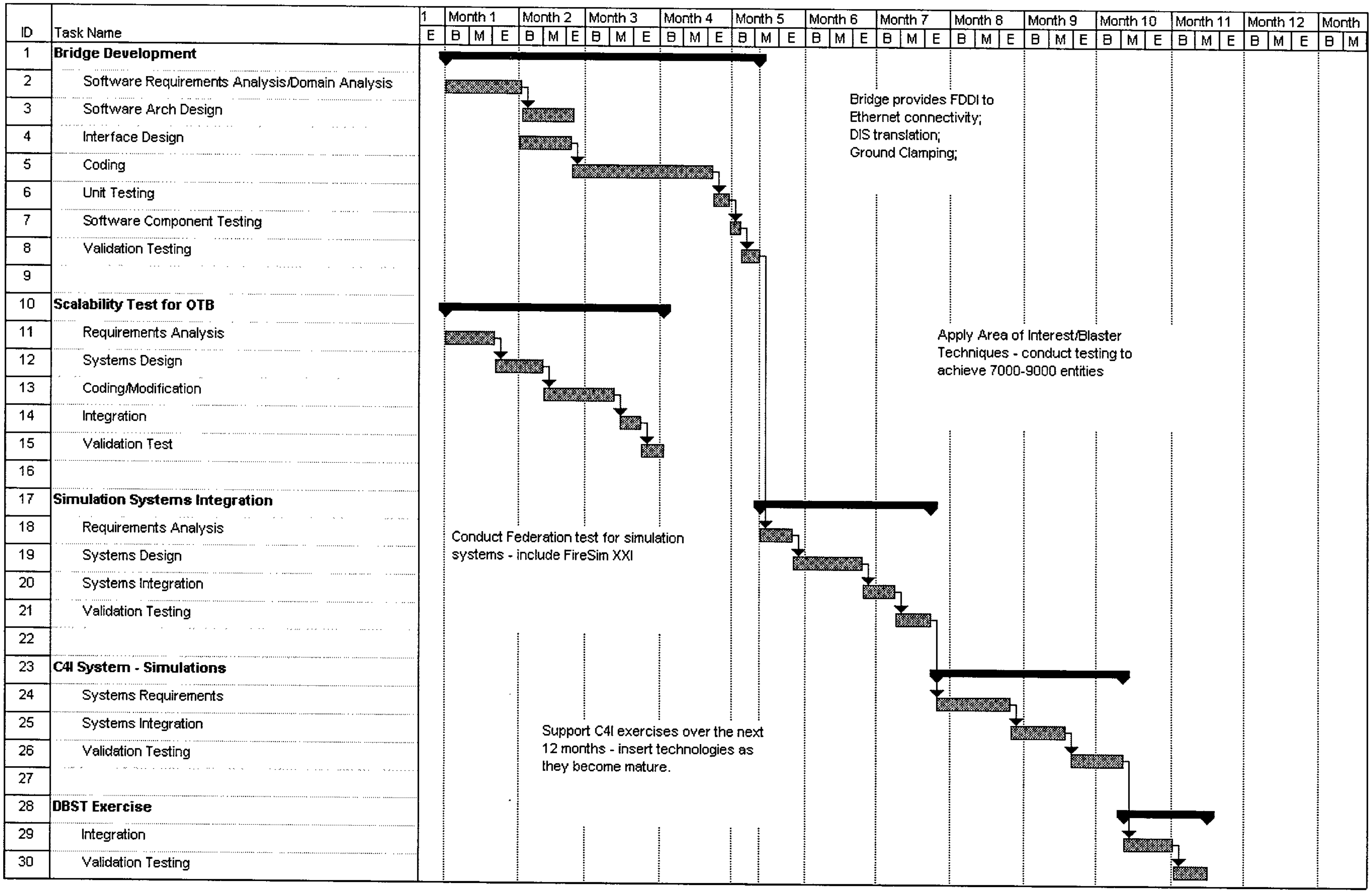
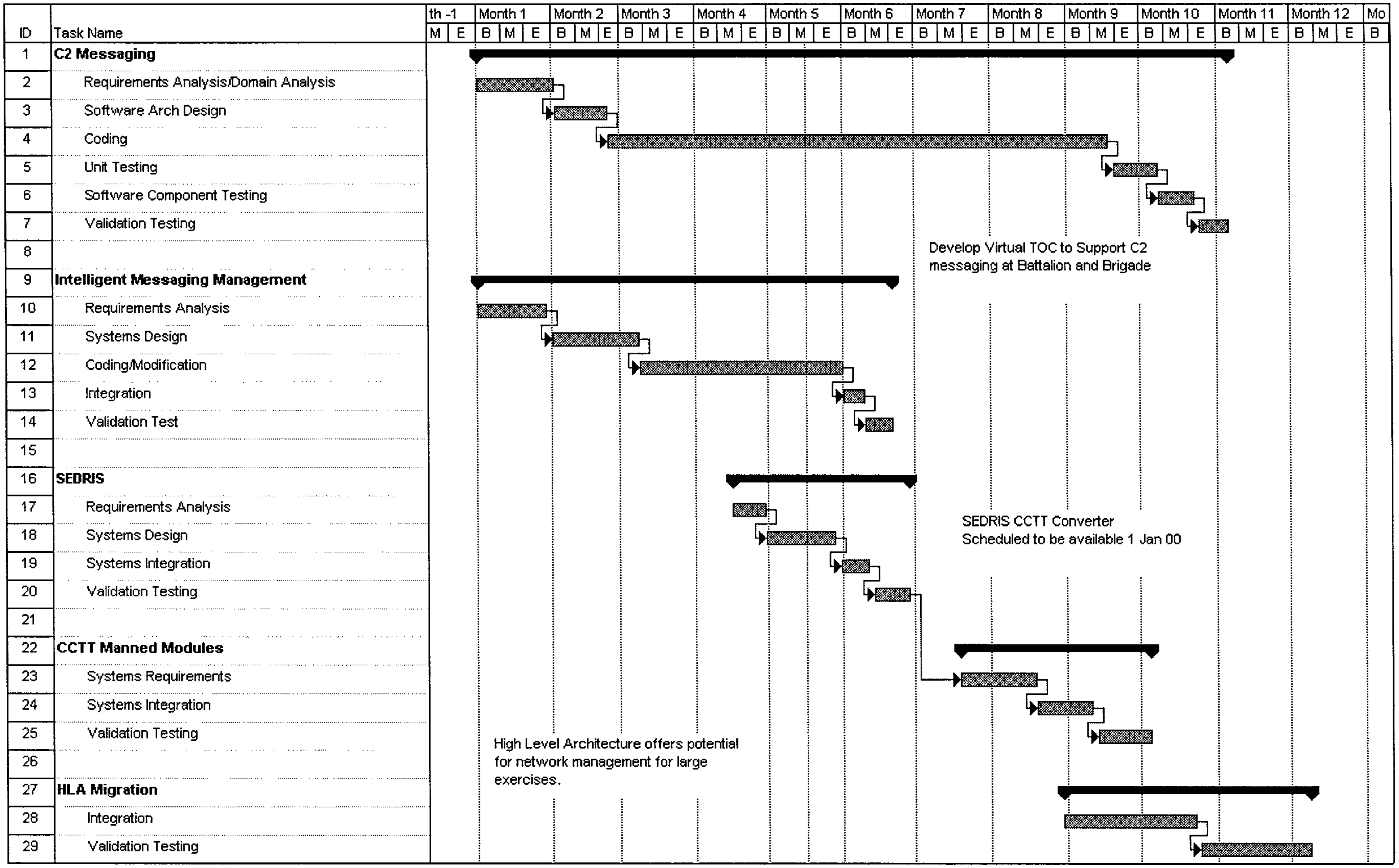


Figure 16 Near Term Development Schedule

7.2.2 Mid Term Capability

The Mid Term will focus on addressing the common SNE for OTB and CCTT SAF as well as development of behaviors to support C2 messaging for SAF to facilitate brigade and battalion operations. Composable behaviors will be developed to address the scalability issues. It is anticipated that this would be developed over a 12 to 24 month period. The following plan provides an approach for achieving this capability;

- SEDRIS Database – testing of SEDRIS databases in support of DBST exercises. This will eliminate the need for ground clamping.
- Development of lower and upper tactical internet messaging and behavior responses in SAF
- Intelligent Interest Management for bridge- develop and test improved network management to enable scalability.
- Manned Modules – introduce the CCTT manned modules into the federation and the DBST training environment.
- HLA – migrate the federation towards HLA to achieve the management offered by developing RTIs to enable participation in larger federations.



Develop Virtual TOC to Support C2 messaging at Battalion and Brigade

SEDRIS CCTT Converter Scheduled to be available 1 Jan 00

High Level Architecture offers potential for network management for large exercises.

Figure 17 Mid Term Development Schedule

7.2.3 Long Term Capability

The long term will focus on addressing increased behavior fidelity for cognitive and physical models in support of command and control. Increased automation of SAF behaviors to develop a near systemic SAF which would require one to two operators to conduct a brigade level exercise. It is anticipated that this would be developed over a 24 to 36 month period. The following plan provides an approach for achieving this capability;

- Behavior models – increased composable behaviors for collective C2 messaging focusing on cognitive and physical models.
- SAF Automation – increasing the behaviors for higher level of commands to facilitate a near systemic SAF.
- C2 Messaging – direct messaging capability from the SAF to the C4I system without the use of middleware.
- Digital/Non Digital System Emulation – Support training for modernized and non-modernized staff training systems.

7.3 Relationship to OneSAF

As discussed above, the development of the SAF confederation between CCTT and OTB will provide the user the ability to select between the best of both the systems. This allows the testing of the concepts of selective fidelity and composable behaviors. Furthermore, the use of the SAF confederation in large scale DBST exercises provides key insights into the requirements OneSAF will have to meet to train the digital Army. As such, this program supports the OneSAF program by providing both technical risk reduction and requirements definition.

8. Cost Estimates

Budgetary cost estimates are provided in the accompanying cover letter for the near and mid term capabilities. These estimates are based on a rough order of magnitude evaluation of the DBST Ground maneuver driver needs. A full, detailed cost proposal can be developed upon acceptance of the technical approach and a detailed requirements document.

9. Conclusion

In summary, the critical question is “Why use the DCT Approach?”

a) Maximum reuse of existing components

  - The building blocks are currently being fielded to operational sites.

- The same components can be connected in a range of configurations to meet a spectrum of use cases.

a) Components are at the start of their lifecycle

- CCTT and OTB are evolving into OneSAF. This helps to speed the merging process.
- The cost of any new development will be amortized over OneSAF's lifecycle.

a) Stepwise Development

- Products will be produced and shown along the entire developmental path.
- By building up from known systems, we can find problems up front and correct them with minimal impact.

a) Minimum artificiality

- C2 Systems fed at the same level as the real world, the entity level, using standard interfaces and with the participants operating in spectrum of use cases from a familiarization mode to a fully task loaded environment.

a) Flexible leave behind for collective training

- This is not a single point solution hacked together for a demonstration.
- Linking the C2 systems to the SAF and Simulators is a capability that can be reconstituted readily in different configurations.

The bottom line is that the DCT approach provides the Army with a product line simulation capability that satisfies spectrum of the short term needs and will evolve to support the emerging long-term needs.

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11. Acronym List

AAR	After Action Review
ABCS	Army Battle Command System
ACR	Advanced Concepts and Requirements
ACTD	Advanced Concept Technical Demonstration
AFATDS	Advanced Field Artillery Tactical Interface Data System
AOI	Area Of Interest
API	Applications Programmer Interface
ASAS	All Source Analysis System
ATCCS	Army Tactical Command and Control System
BBS	Brigade and Battalion Simulation
BCST	Battle Command/Staff Trainer
BDA	Battle Damage Assessment
BEWSS	Battlefield Environment Weapon System Simulation
BLUFOR	Blue Force
C2	Command and Control
CAS	Close Air Support
CCTT	Close Combat Tactical Trainer
CFOR	Command Forces
CFS	Command From Simulator
CGF	Computer Generated Forces
CIS	Combat Instruction Set
CP	Command Post
COFT	Conduct of Fire Trainer
CTDB	Compact Terrain Database
DAR	Data Analysis Report
DARPA	Defense Advanced Research Projects Agency
DBST	Digital Battlestaff Sustainment Trainer
DCT	Digital Collective Training
DCX	Division Capstone Exercise
DDM	Digital Data Manager
DFSST	Division Fire Support Simulation Trainer
DI	Dismounted Infantry
DI WS	Dismounted Infantry Workstation
DIS	Distributed Interactive Simulation
DMI	Digital Messaging Interface
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DRA	Dead Reckoning Algorithm

DRC	Daily Readiness Check
DT	Dynamic Terrain
DTO	Dynamic Terrain Objects
DVW	Dynamic Virtual World
EADSIM	Extended Air Defense Simulation
ECN	Engineering Change Notice
EM	Environment Model
EmTDB	Environment Model's Terrain Database
FDDI	Fiber Distributed Data Interface
FM	Field Manual
FRAGO	Fragmentary Order
GUI	Graphical User Interface
HLA	High Level Architecture
ICT	Integrated Concept Team
IDE	Integration Development Environment
IDT	Integrated Development Team
IP	Internet Protocol
IV&V	Independent Verification and Validation
JCM	Joint Countermine
JCOS	Joint Countermine Operations
JTS	Joint Tactical Simulation
JVMF	Joint Variable Message Format
LOD	Low Overhead Driver
LOS	Line Of Sight
LUT	Limited User Test
M&S	Modeling and Simulation
MCC	Master Control Console
MCS	Maneuver Control System
MGRS	Milgrid
MHz	megahertz
MM	Manned Module
MMCM	Magnetic Mine Counter Measure
ModSAF	Modular Semi-Automated Forces
MrsTDB	Multi-level Routing Support Terrain Database
MrTDB	Model Reference Terrain Database
MTBF	Mean Time Before Failure
NFS	Network File System
NSC	National Simulation Center
NTC	National Training Center
NTP	Network Time Protocol
OC	Operations Center
OC WS	Operations Center Work Station
OPFOR	Opposing Force
ORD	Operational Requirements Document
OTB	OneSAF Testbed

PDU	Protocol Data Unit
POP	Persistent Object Protocol
PVD	Plan View Display
R&D	Research and Development
RAM	Random Access Memory
RTI	Runtime Infrastructure
SAF	Semi-Automated Forces
SAF WS	Semi-Automated Forces Work Station
SATIDS	Situational Awareness Tactical Internet Data Server
SEDRIS	Synthetic Environments Data, Representation and Interchange Specification
SEOD	Semi-Automated Forces Entity Object Database
SIF	Standard Interchange Format
SLOC	Statement Lines Of Code
SME	Subject Matter Expert
SNE	Synthetic Natural Environment
SOM	Simulation Object Model
STOW	Synthetic Theater Of War
STRICOM	Simulation Training Instrumentation Command
TAOS	Total Atmospheric and Ocean Server
TEMO	Training, Exercise, Military Operations
TF	Task Force
TO	Task Organization
TOC	Tactical Operations Center
TSIU	Tactical Simulation Interface Unit
TSP	Training Support Package
UCI	User Computer Interface
UID	User Interface Data
UIL	User Interface Language
UTM	Universal Transverse Mercator
VMF	Variable Message Format
VV&A	Validation, Verification and Accreditation
WFX	Warfighter Exercise
WS	Work Station

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