

PROTOTYPING ADVANCED WARFARE GAMING CAPABILITIES FOR THE 21ST CENTURY WARFIGHTER

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ABSTRACT

The United States Marine Corps has a unique role in development of the next-generation warfare gaming system for command staff training. This system, titled the Joint Simulation System (JSIMS), is under development by the Department of Defense through a Joint Program Office acting to coordinate the activities of multiple DoD agencies and military services. The nature of operations conducted by the USMC requires modeling and simulation across all JSIMS domains – Land, Air/Space, Maritime, Intelligence, and Command and Control. The Marine Corps requires the broadest reach across these domains to provide battlespace representations that will support staff training, from Marine Expeditionary Unit through multiple Marine Expeditionary Force operations.

This paper describes the Marine Corps approach to ensure USMC requirements are achieved across the JSIMS enterprise. The paper also describes investigations into exercise control and exercise conduct capabilities for the USMC JSIMS product, working from the foundation of the Marine Air-Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS), the USMC's fielded command staff trainer. Prototyping efforts include exercise analysis and review capabilities; an integrated Command, Control, Communications, Computers and Intelligence (C4I) and Exercise Control workstation architecture; interoperability of real-world C4I systems with the simulation system; and exercise data preparation tools.

1 INTRODUCTION

The United States Marine Corps is a leader in development of automated systems supporting command staff training. Starting from computer-supported fire support lessons in the early 1970's, to fielding of the Tactical Warfare Analysis and Evaluation System (TWAES) assisting management of Field Exercises (FEX) in 1974 and the Tactical Exercise Simulation and Evaluation (TESE) system for managing conduct of Command Post Exercises

(CPX) in 1976, to fielding of the Marine Air-Ground Tactical Warfare Simulation (MTWS) in 1995, the Marine Corps has a long history of successful development of warfare simulation systems. Advances in computer technology over these past 25 years have enabled an evolution from early, simplistic automated support tools for staff training to complex, high-capacity command staff training systems available and in development today. Command staff training systems for the 21st Century will support a broad range of training requirements, from small team to large, joint and even multinational forces.

Not only has the scope of training broadened, but operational Command, Control, Communications, Computers, and Intelligence (C4I) procedures and tools have evolved. The military services are rapidly introducing automated C4I systems into the field, creating interoperability challenges for warfare simulation systems. Together with C4I architecture enhancements, evolving military tactics and rapidly changing force structures are creating numerous technological challenges for the next generation of command staff training systems. The technical challenges can be divided into three areas:

- System Architecture – composable hardware and software architectures necessary to support training of multiple staff hierarchies at multiple levels of resolution
- Exercise Control Tools – automated and semi-automated tools enabling smaller numbers of exercise control personnel to prepare, conduct, and evaluate exercises of greater complexity and scope
- Warfare Simulation – expanded combat simulation and C4I models providing multiple levels of resolution, including entity-level representations and varying levels of aggregation

This paper focuses primarily on work in the area of Exercise Control Tools, describing investigations into advanced capabilities underway by the USMC.

2 JSIMS AND MTWS

The US Marine Corps is working with the US Army, US Navy, US Air Force, and several Department of Defense agencies to develop the next-generation training system for Joint command staffs, the Joint Simulation System (JSIMS). While the other services have Development Agent responsibilities in JSIMS, the USMC is in the unique position of requiring significant capabilities across all domains of Air/Space, Land, Maritime, Intelligence, and C4I. Marine Corps requirements for JSIMS are specified in an Operational Requirements Document (ORD) and a System/Subsystem Specification (SSS). USMC requirements have been integrated into the JSIMS Enterprise SSS. To ensure USMC requirements are satisfied across the JSIMS Enterprise, the USMC has placed technical representatives in the Integration and Development, Land, and Air/Space contractor facilities (Orlando, Florida) to work hand-in-hand with the respective engineering staffs. These representatives provide clarification of USMC JSIMS requirements, monitor development plans and progress within those domains, and test implemented capabilities to

verify achievement of USMC requirements. Moreover, at the Space and Naval Warfare (SPAWAR) Systems Center, San Diego, USMC JSIMS development personnel are working with the Navy's JSIMS Maritime engineering staff to develop Marine Corps specific requirements (e.g., objects and behaviors relating to amphibious operations and littoral warfare).

The USMC plans to replace MTWS with the Initial Operational Capability (IOC) version of JSIMS, scheduled for fielding in April 2001. During this interim period between now and IOC, the USMC is continuing a program of architectural and simulation upgrades (Blais 1995) to MTWS to maintain a high-quality, state-of-the-art warfare gaming system supporting Fleet Marine Force and Joint training requirements. The USMC is also employing MTWS as a platform for development and demonstration of functional prototypes to explore capabilities and further refine requirements desired in the future USMC JSIMS. Since its fielding in 1995, MTWS has proven to be an excellent platform for developing enhanced capabilities and for performing prototyping studies. MTWS meets approximately 75% of the USMC JSIMS requirements, and over 50% of the JSIMS Joint/Service (CINC-level) requirements. Therefore, MTWS provides an operational capability that is similar in scope to future JSIMS capabilities, for USMC-only and for joint exercise play.

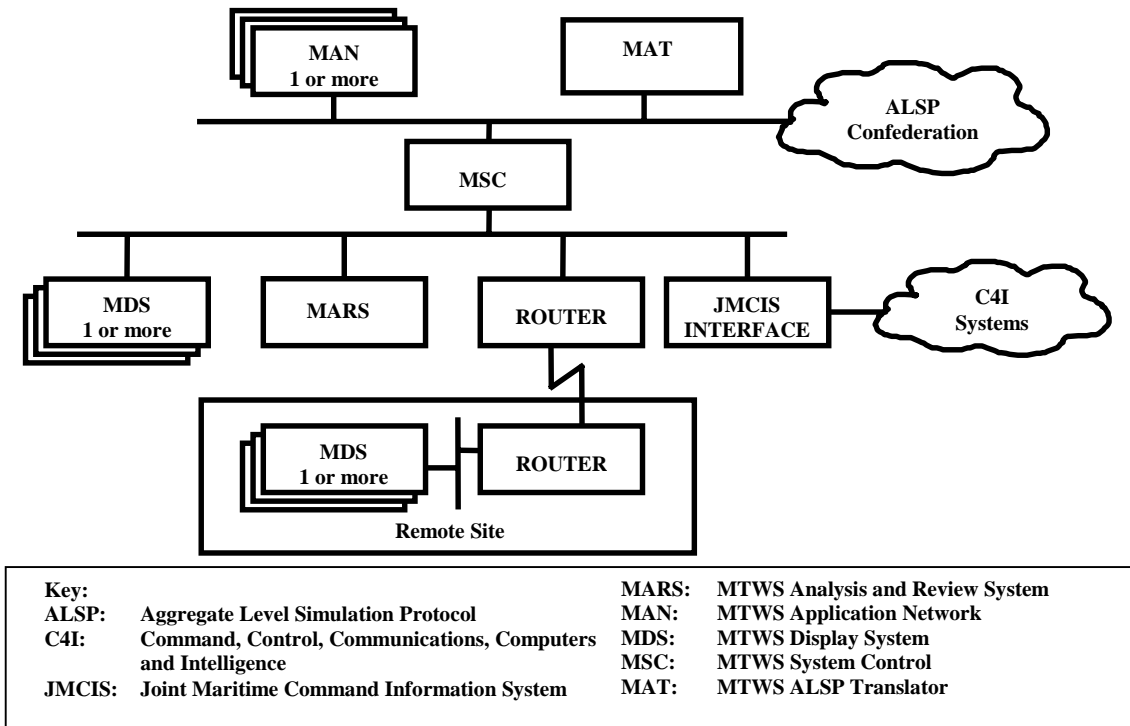


Figure 1: MTWS System Architecture

Figure 1 provides an overview of the current MTWS system architecture, showing optional connectivity for participation in an Aggregate Level Simulation Protocol (ALSP) Confederation, interactions with real-world C4I systems, and operation at a remote site. MTWS comprises the following major components (refer to Blais 1994 for a brief functional description of the MTWS system):

- MTWS Application Network (MAN) – distributed workstations performing combat simulation (e.g., ground combat, fire support, air operations, combat service support, combat engineering, intelligence)
- MTWS System Control (MSC) – provides archival exercise data storage and retrieval, report generation, restart, and exercise gametime management
- MTWS Display System (MDS) – user workstations enabling command entry, report request, report display, map display, tactical data display, parametric data editing, batch file creation and maintenance, and batch file entry
- MTWS ALSP Translator (MAT) – performs communications between MTWS and diverse simulation systems using ALSP
- MTWS Analysis and Review System (MARS) – provides analytical tools for display, reporting, and charting time-tagged exercise data during and after exercise conduct (see paragraph 5 below)

3 THE EXERCISE CONTROL CHALLENGE

The JSIMS System Specification states the requirement to “provide an integrated set of tools that automate the pre-exercise, execution, evaluation, and post-exercise phases of a simulation event in order to reduce personnel overhead by 67% as compared to the FY 1999 ALSP Joint Training Confederation” (requirement number 80003, TRW 1997). This is one of the most challenging requirements facing the JSIMS development teams.

Figure 2 shows the traditional method of exercise control practiced in the USMC for computer-assisted command staff training. A team of trained specialists called the Tactical Exercise Control Group (TECG) acts as the intermediary between the simulation system and the personnel being trained (“player staff”). This is necessary to maintain a realistic environment for the player staff. The player staff performs their C2 decision-making roles just as they would in the field. The exercise control staff acts as role-players – higher, lower, or adjacent command levels, or other C4I agencies in the command and control structure. In addition, the exercise control staff has

responsibility for ensuring training objectives are met and that the player staff is given a challenging and valuable training experience. Communications between the player staff and exercise control team are established to replicate or emulate field communications systems, often employing doctrinal communications nets on actual tactical radio equipment. Generally, the exercise control staff also plays the Opposing Force, although it is possible to have two player staffs operating through intermediary control staffs to create a full, two-player game. Personnel from the exercising unit often man the exercise control team (e.g., when a battalion staff is exercised, company level commanders and platoon leaders within the battalion organization may be assigned to the exercise control staff). Although placed in an artificial environment as intermediaries between the player staff and the simulation, these personnel also obtain valuable experience in command and control procedures and interactions through the exercise control role.

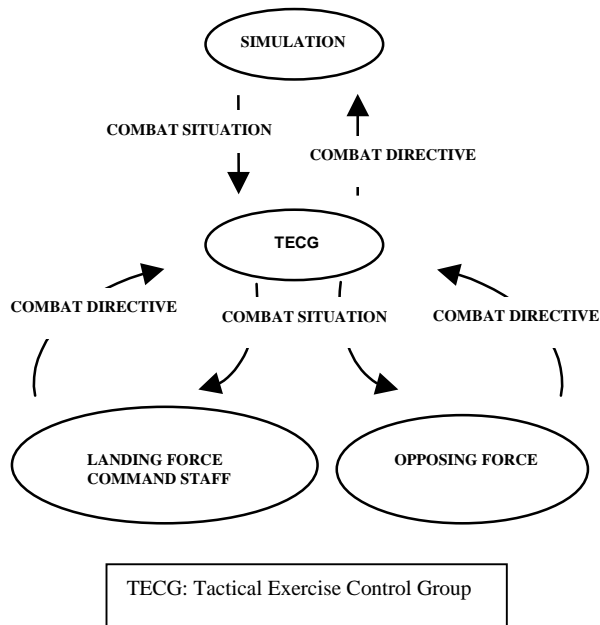


Figure 2: Traditional Exercise Conduct

In the traditional structure, alternatives for reducing the exercise control staff are limited. One approach is to improve their efficiency by enabling the exercise control staff to increase the number of game objects (such as ground units, air missions, and ships) and game events they are able to manage (by such actions as maneuver, fire, and reporting). This can be achieved by providing improved game management tools, such as simplified entry of commands and greater visualization of object status and occurrence of game events. All of the service models have gone through varying levels of development evolutions that implemented such improvements; for

example, improvements in MTWS simplifying entry of Fire Mission commands and creating visual indication of ground engagements and unit strength.

A second approach is to reduce the exercise controller workload by building greater intelligence and autonomy into the game objects so that the objects need less attention and direction from the exercise control staff. Such projects as Modular Semi-Automated Forces (ModSAF) and Synthetic Theatre of War (STOW) have used this approach. However, a disadvantage in such autonomy is the loss of the spontaneity and unpredictability of a human opponent, at least until such systems have far greater sophistication than is currently implemented.

The fielding of automated C4I systems creates greater opportunity for interaction, as shown in Figure 3. It now becomes possible to consider opportunities for direct communications between the player staff and the simulation through tactical message systems employed in the C4I systems. However, with the opportunity comes greater complexity. The simulation must have the software tools to parse and operate on the commands and directives received from the player staff. In addition, the simulation must have the intelligence to create proper tactical messages relating to the occurrence of game events and must ensure that the messages are addressed to the correct elements of the command and control organization. This is complicated by the fact that different exercises can have different target training audiences, and therefore require different configurations of exercise control staff roles and simulation software responsibilities. For example, an exercise for a battalion staff could have a Fire Direction Center (FDC) represented by actual player personnel (part of the training audience), by exercise control personnel, or completely modeled by the simulation software.

4 EXERCISE CONTROL TOOLS

The USMC is vigorously investigating alternative approaches and capabilities relating to improvements in exercise control. The principal targets for prototyping efforts are briefly introduced below, and then covered in more detail in sections 5 through 8 of this paper.

4.1 Exercise Analysis and Review

Exercise controllers and analysts require tools to facilitate collection, visualization, manipulation, reduction, and evaluation of exercise data. Exercise data includes initial exercise data, time-stamped changes to game objects that occurred during the exercise, time-stamped orders entered by controllers based on their own initiative or in response to orders/directives from the player staff, and time-stamped events that occurred during the exercise. Previously, such tools were called “after action review” (AAR) tools, but we choose to refer to them more generally as “analysis and review” tools to convey their availability to the control staff before, during, and after exercise execution. Analysts use the tools to determine causality relationships between player decisions and game events and outcomes, as well as to prepare after action briefings. The objective of the prototyping effort is to refine the USMC analysis and review requirements for JSIMS.

4.2 Exercise Control Workstation

The USMC is rapidly fielding automated C4I systems in accordance with Global Command and Control System (GCCS) standards. Current systems, such as Tactical Combat Operations (TCO) and the Intelligence Analysis System (IAS), have been developed as adaptations of the Navy’s Joint Maritime Command Information System (JMCIS). In order to stimulate the training audience, modern simulation systems such as MTWS must interoperate with the C4I systems. Exercise control personnel performing as role players in the exercise use the real-world C4I systems to enter and process tactical messages and to visualize the battlespace, just as they would in the field. Currently, however, this often requires the control staff to operate multiple workstations – one for interfacing with the simulation system and one or more for performing real-world C4I actions. This means additional training time for exercise control personnel to learn multiple user interfaces and involves additional hardware set-up to support the exercise conduct.

A solution to this problem is creation of a single exercise control workstation that supports both controller responsibilities; namely, interactions with the simulation system and interactions with the C4I system(s). We are prototyping a workstation architecture by integrating an updated version of the MTWS Display System software

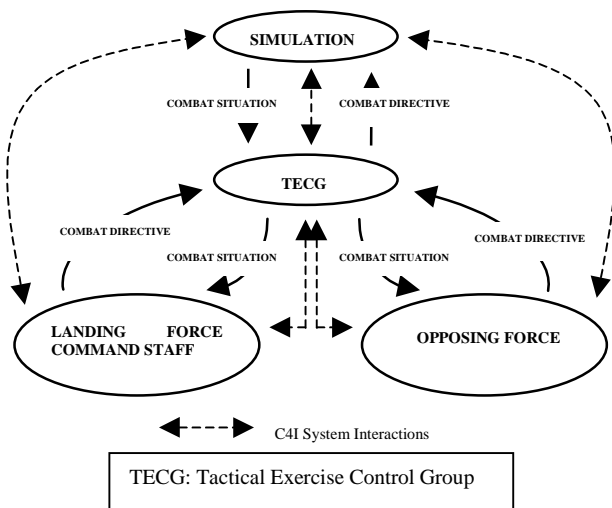


Figure 3: Evolving Exercise Conduct

with software providing JMCIS-compatible C4I functionality. The objective of the prototyping effort is to introduce an initial workstation architecture to the operational sites for use in MTWS exercises. This will create opportunity to obtain user feedback and to derive an employment concept for the integrated capability. The prototype controller workstation will also be adapted for use in early JSIMS model builds to assist in system testing and system demonstration.

4.3 C4I Interoperability

As discussed earlier, the growing use of automated C4I systems creates the opportunity for greater transfer of information directly from the simulation system to the real-world C4I systems, and vice versa, without involvement of human intermediaries (exercise control staff). A clear reduction in exercise control personnel will result as more of the interactions can be implemented in the simulation software. Role-player responsibilities can be automated, in whole or in part, reducing the workload on the exercise control staff. The objective of the prototyping effort is to introduce C4I interoperability to the operational sites for use in MTWS exercises enabling the techniques to be refined for exercise use and for employment in tactical decision making.

4.4 Exercise Data Preparation

There is increasing demand for simulation systems that provide higher quantities of game objects at higher resolution, creating added complexity to the effort of building the initial exercise database. Examples include: parametric data describing weapon system, sensor, and vehicle characteristics; force structures; force lay-downs; and start-up plans and schedules, such as air tasking, beach preparation fires, tasking of reconnaissance and surveillance assets, and amphibious operations. VisiCom has developed a prototype tool that simplifies generation of the exercise database. The objective of the prototyping effort is to demonstrate alternative approaches to exercise data preparation for user evaluation and feedback, from which a more complete set of requirements can be generated.

5 ANALYSIS AND REVIEW SYSTEM

In May 1997, the MAGTF Staff Training Program Center (MSTPC) specified an initial set of requirements for an Analysis and Review System (ARS). The requirements were defined in the context of the following Battlespace Functions (an example requirement is provided parenthetically):

- Maneuver (e.g., graphic depiction of ground unit movements over user-selected periods of time)
- Intelligence (e.g., report a roll-up of Opposing Force units observed by organic reconnaissance assets of a Marine Expeditionary Force)

- Firepower (e.g., Landing Force attacks on high-priority target list items, by mission priority and by category)
- Logistics/Combat Service Support (e.g., graphically display medical units, Medical Evacuation missions, and transfers of wounded/killed personnel)
- Command and Control (e.g., graphical depiction of fire support measures or maneuver control measures violated during the exercise)
- Force Protection (e.g., report fratricide from friendly fires)

Gibson (1995) describes a similar breakout of requirements for the Army Corps Battle Simulation (CBS) in terms of eight Battlefield Operating Systems. MSTPC also specified requirements relating to Opposing Force (e.g., report Opposing Force units in hierarchical order), Combat Analysis (e.g., select ground units in an area and report cumulative combat power, by side, identifying combat systems and assets, including personnel), and Graphics (e.g., boundary lines, objectives, landing zones, phase lines).

To create the prototype ARS on MTWS, we exploited the set of message formats used to pass database updates across the system's distributed architecture. When data updates are recorded in the MSC, a copy is sent over the network (using Transmission Control Protocol/Internet Protocol (TCP/IP)) to a workstation acting as the ARS data server. Other workstations on the network run client software to access data from the server. The client software can display graphics overlaid on map images, produce textual reports of requested data, and produce simplistic charts graphing requested data.

In addition to database updates, several events initiate data transfers to the ARS. These events include the use of certain exercise control commands, such as Unit Locate and Unit Asset Update, to enable exercise analysts to identify and evaluate controller actions taken during the exercise.

Because the information is sent to the ARS server during the running of the system, analysts at the ARS workstations can access and display historical data at any time during or after the exercise. This allows near real-time evaluation of exercise situations and results while the ARS server continues to accumulate ongoing game data.

The server and client software are adaptations of a commercial product called Vision XXI from Tapestry Solutions, Incorporated (Tapestry 1998). The product was modified to recognize MTWS data structures and to provide manipulation of the data to meet the specified MSTPC requirements.

6 EXERCISE CONTROL WORKSTATION

The Marine Corps has embraced the principles stated in the Navy's Information Technology for the 21st Century (IT-21) initiative. In the years since the architecture of the current

Defense Information Infrastructure Common Operating Environment (DII COE) was conceived, DoD and the Defense industry have moved in some significant directions. These include: (1) a move away from the UNIX operating system toward Microsoft Windows NT; (2) a move away from the relatively high-cost UNIX-capable hardware, toward Intel-based hardware capable of running Windows NT; (3) a move away from local area network (LAN) centric systems toward Wide-Area-Network (WAN) centric systems (i.e., the Internet and Intranets); and (4) a decline in the use of the Ada language for commercial software development. The movement toward Windows NT was evident at the Interservice/Industry Training Simulation and Education Conference (IITSEC) held in Orlando, Florida in December 1997: "...what was truly striking as one talked to the exhibitors and toured the booths and read the announcements, was the growth in the number of Windows NT-based simulations and the inexorably growing number of applications being written for the Microsoft-based operating system" (Silverberg 1998).

The trend towards Windows NT is a particularly important one. Since its release, Microsoft's Windows NT operating system has been steadily encroaching on the market previously occupied by the various flavors of UNIX. This is primarily the corporate or "enterprise" market. NT has been a success due to three main factors:

- Users are often familiar with the Windows environment and Microsoft Office tools from home Personal Computer (PC) use and therefore find Windows to be the most productive environment for doing their work.
- Microsoft's implementation of a number of key enterprise computing requirements (such as multiprocessor scalability and a C2-accredited security model coming standard with the operating system) mostly match their counterparts in UNIX. NT version 5.0, according to Microsoft's marketing material, is set to surpass the enterprise capabilities of existing UNIX operating systems with features such as global directory management based on internet-standard protocols and Kerberos-based security.
- The purchase cost of hardware, software, and operating system for Windows environments is typically an order of magnitude lower than in the UNIX world.

Overall, there is commitment toward Windows NT as a less expensive system to procure and operate, a more manageable system for systems administrators, and a more productive, interoperable environment for individual users. It is now common to see the standard desktop of a DoD user comprising Windows NT, Microsoft Office, Lotus, a web browser, and a situation monitoring application. Commercial Off-the-Shelf (COTS) and specialist applications can then be

added, configured as server applications accessed via the web browser, Notes applications distributed via Notes replication, or as standard application packages.

In addition to the migration to Windows NT, there is great industry interest in the Java programming language for developing net-based applications. Advantages of Java as the software language of choice include: (1) platform independence; (2) mainstream software engineering tools and skills; (3) rich, integrated Application Program Interface (API) set; (4) object-oriented programming methodology; and (5) user system safety.

In section 4.2, we introduced the vision of a unified exercise controller and C4I workstation. Given the impetus toward the Windows environment, internet/intranet operation, and Java implementation, these technologies were chosen for the foundation of the Exercise Control Workstation prototype. We are migrating current MDS functionality to provide the exercise control capabilities. This functionality will be integrated with Windows-based C4I software, such as that provided in the Enhanced Common Operational Picture (ECOP) or the Command and Control Personal Computer (C2PC).

The prototype Exercise Control Workstation will be delivered to the Marine Corps for evaluation in the Spring of 1999. We anticipate that the workstation will enhance operator performance and provide a richer training environment for exercise control staff personnel, especially those performing as role players needing access to and interaction with the real-world C4I systems.

With the creation of a single workstation providing both exercise control and C4I system operation, the next step in system evolution is straightforward. Rather than thinking of the simulation system as external to the real-world C4I system, it should be seen as a decision-making tool embedded in the C4I system. This concept is discussed in detail in Garrabrants (1998).

7 C4I INTEROPERABILITY

There has been considerable focus on interoperability of C4I and simulation systems in recent years as C4I systems have been introduced into service use. One approach that has received great attention in the modeling and simulation community is the Modular Reconfigurable C4I Interface (MRCI) program (Hieb et. al., 1997):

The function of the MRCI is to provide bi-directional, logical interactions between organic C4I systems and HLA-compliant simulation federations to provide field commanders with tools to stimulate, monitor, or interact with these federations.

MRCI provides a common interface tool between diverse C4I systems and diverse simulation systems. Various message protocols are processed into a uniform message

structure, promoting reuse of common communication modules and simplifying introduction of new messages and systems into the overall architecture. Interactions use the Command and Control Simulation Interface Language (CCSIL) as the prototype C2 Data Interchange Format (DIF). Outgoing C4I system messages are translated into CCSIL from tactical message formats, such as the US Message Text Format (USMTF). Messages to a C4I system are translated from CCSIL format into the standard tactical message formats used by that system. Simulations send CCSIL messages to MRCI, and receive CCSIL messages from the MRCI through the High Level Architecture (HLA) Run Time Infrastructure (RTI).

However, MTWS has not been upgraded to become HLA compliant, and the Marine Corps has determined that this would not be cost-effective in light of the imminent USMC JSIMS product (IOC 2001). Lacking this infrastructure, we took a more direct, but less robust, approach in the development of a prototype capability. The following techniques have been employed for the different types of messages or message formats:

- Over-the-Horizon (OTH) Gold OPNOTES: As events occur in the simulation, brief textual reports (spot reports) are generated in a simulation processor (i.e., MAN) and routed to an appropriate user station (MDS). If the interface is activated, the spot report text is placed into the data portion of a OPNOTE and injected into the C4I system. The message formatting is performed on the MDS station.
- OTH-Gold JUNIT, JPOS, and CONTACT messages: When certain information affecting data used by the MTWS Display Systems (user stations) for tactical display and reporting is received at the MDS, this subset of OTH-Gold messages is generated and injected into the C4I system. The message formatting is performed on the MDS station.
- USMTF messages (e.g., RECCEXREP, TACELINT): As events occur in the simulation, these messages are created in the simulation processor (i.e., MAN) and sent to an MDS station for injection into the C4I system.
- Air Tasking Orders (ATO): When an ATO is received by a JMCIS station (i.e., from the Contingency Tactical Air Planning System (CTAPS)), the operator can send the ATO file to an attached MDS. The ATO is routed to a simulation processor and parsed to create MTWS simulated air missions.

Interoperability with C4I systems is more than just message interactions. For future work, we propose defining a framework for assigning C4I roles and responsibilities

across the simulation system, the exercise control staff, and the player staff. The assignments are exercise dependent. That is, depending on the organization of the command staff to be trained and the roles and responsibilities assigned to the exercise control staff, the simulation system needs to determine or be told what C4I elements to simulate. For example, a Fire Direction Center (FDC) may be part of the training audience, played by exercise control staff, or modeled in the simulation. A promising framework for such an approach is described in Phelan and McGinnis 1996.

8 EXERCISE DATA PREPARATION

Given the widespread availability of PCs, we developed a prototype exercise data preparation tool using a common commercial database product. The tool, named APEX, provides a simple user interface to create and modify MTWS parametric data, tables of equipment, and command batch files.

The parametric data tool allows the user to create MTWS simple weapons, sensors, and platforms, and to build complex assets from a combination of these components. The resulting parametric data can be written to file and imported into the MTWS system. Conversely, existing MTWS parametric data describing asset characteristics can be written to file and imported into APEX for editing by the user on the PC.

Tables of equipment (TEs) provide the names and quantities of equipment, personnel, and supplies associated with standard organizational structures, such as a Marine Infantry Company or an Army Tank Platoon. These are defined to facilitate creation and initialization of standard force packages, which can then be modified individually by MTWS commands to create specialized force packages for an exercise. As with the parametric data, the TEs can be loaded to/from MTWS database files.

APEX also provides a set of MTWS commands that can be called out by the user and stored in batch files for later input to MTWS. A batch file stores one or more MTWS commands that can be entered into the system at one time; for example, to load in the definition of ship-to-shore elements and the landing schedule to build a plan for an amphibious landing. The commands are stored as simple text strings. APEX provides a simple user interface providing a selection of commands and their parameters, and the mechanisms for creating, storing, and modifying the commands, and for generating batch files containing selected commands.

9 SUMMARY

The Marine Corps is leading the way into the 21st Century through an innovative program of prototype development to explore advanced warfare gaming capabilities. These efforts will benefit current operational forces through

improvement of the MTWS system, and will provide a vehicle for greater understanding of USMC requirements within the JSIMS development community.

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