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THESIS

**INTEGRATION OF CONSTRUCTIVE SIMULATIONS
TO LOGISTICS COMMAND AND CONTROL TRAINING
DESIGN AND EXECUTION**

by

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June 2019

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**INTEGRATION OF CONSTRUCTIVE SIMULATIONS TO LOGISTICS
COMMAND AND CONTROL TRAINING DESIGN AND EXECUTION**

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ABSTRACT

This research was conducted to examine the potential for constructive simulation to increase the efficiency at which logistics command and control (C2) training objectives are achieved. As a continuation of the “Integration of Simulated Logistics Information and Information Technology Tools in Support of Marine Corps Simulated Exercises” thesis by E. Conard in 2018, this research conducts practical application testing of Conard’s conclusions. Five analyses were conducted on three Department of Defense simulations to determine the utility of individual or federated systems in logistics C2 training. The Marine Air Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS), the Joint Conflict and Tactical Simulation (JCATS), and the Joint Deployment Logistics Model (JDLM) were evaluated individually, and as federated systems with MTWS connected to JDLM and JCATS connected to JDLM. Gap analysis methodology was used to examine the Marine Corps Logistics Operations Group (MCLOG) logistics C2 training design, identify limitations, and determine where constructive training tools can be used to enhance training. The analyses resulted in the recommendation that MCLOG incorporate JDLM into the current training design via an HLA federation with MTWS. The recommended configuration accounts for ease of integration, the fidelity of logistics data generated by the simulations, and the capability of the configuration to support simultaneous training of logistics components across the MAGTF.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACE	aviation combat element
BFG	batch file generator
BFT	Blue Force Tracker
C2	command and control
C2PC	Command and Control Personal Computer
CAAT	combined anti-armor team
CART	Combat Analysis and Review Toolkit
CAS	close air support
CE	command element
CESI	Cole Engineering Services Incorporated
CLC2S	Common Logistics Command and Control System
CMC	Commandant of the Marine Corps
COC	command operation centers
DIS	distributed interactive simulation
DoD	Department of Defense
DODIC	DoD identification code
FOM	federated object model
GCCS-TCO	Global Command and Control System - Tactical Combat Operations
GCE	ground combat element
HLA	High level architecture
IP	internet protocol
J7	Joint Force Development Directorate
JCATS	Joint Conflict and Tactical Simulation
JDLM	Joint Deployment Logistics Model
JLVC	joint live, virtual, and constructive
JS DDJT	Joint Staff Deputy Director Joint Training
JTDS	Joint Training Data Service
KIA	killed in action
LCE	logistics combat element

LLNL	Lawrence Livermore National Laboratory
LVC	live, virtual, and constructive
MAGTF	Marine Air Ground Task Force
MAN	Model Application Network
MCLOG	Marine Corps Logistics Operations Group
MDS	Model Display System
MEF	Marine Expeditionary Force
MLS2	MAGTF logistics support systems
MOS	military occupational specialty
MSC	Model System Control
MSEL	master scenario event list
MSTP	MAGTF Staff Training Program
MTD	MAGTF Training Directorate
MTWS	MAGTF Tactical Warfare Simulation
NIIN	national item identification number
OBS	order of battle service
OPFOR	opposing force
OS	operating system
PhPk	probability of hit probability of kill
RHEL	Red Hat Enterprise Linux
RTI	runtime infrastructure
SOP	standard operating procedure
STARTEX	start exercise
TAMCN	table of authorized material control number
USMC	United States Marine Corps
WIA	wounded in action
XML	extensible markup language

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This research was greatly enhanced by the enthusiastic cooperation of both industry and military components. The funding allocated through TECOM provided the means to purchase the necessary hardware to establish the constructive simulation lab in the MOVES department, and supported travel to gain experience with constructive simulation and observe federations used during training operations. The MOVES department was honored to host personnel from MSTP, LLNL, Tapestry Solutions, and the J7 throughout this research, all of whom provided both their time and subject-matter expertise assisting in the development of the constructive simulation lab and scenario development for analyses. Researchers had the pleasure of visiting the MCLOG, MSTP, LLNL, and the J7 to gain fundamental knowledge in how constructive simulations are used in training operations, both as standalone simulations and widely distributed federations. Personnel from all units and companies listed provided constant assistance, ensuring the complete development of the constructive simulation lab and that all requirements were met to conduct analyses. Without their diligent and patience assistance, this thesis would not have been possible.

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I. INTRODUCTION

The Commandant of the Marine Corps (CMC) identified the uses of simulation in training as one of the five areas of effort for success (CMC, 2016a). In response, the Marine Corps has made it a priority to utilize live, virtual, and constructive (LVC) systems as a spectrum of tools that can be used individually or integrated as required to facilitate training objectives. This initiative creates an extensive collection of training aids which foster increased training capability, flexibility, and tailoring to meet specific objectives. While advancements have been made to implement live and virtual capability to the lowest level, gaps have been identified in the constructive simulation realm. Logistics functionality in constructive simulation, in particular, remains generic and simplified in systems utilized by the Marine Corps (Conard, 2018). The following research was conducted to consider alternatives to existing logistics command and control (C2) training design to more effectively incorporate constructive simulation. The following is a general overview, all prominent or unique technical terms within this publication are defined in the last section of this chapter for reference.

A. PURPOSE

The purpose of this research was to examine the potential for integration of constructive simulation into logistics C2 training design and execution. Five analyses were conducted on three Department of Defense (DoD) simulations to determine the utility of individual or federated systems in logistics C2 training. The following simulations: Marine Air Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS), the Joint Conflict and Tactical Simulation (JCATS), and the Joint Deployment Logistics Model (JDLM) were evaluated individually, and as federated systems with MTWS connected to JDLM and JCATS connected to JDLM. Each analysis yielded strengths and weakness to support C2 training across the logistics community.

B. PROBLEM STATEMENT

Military logistics is comprised of all actions required to sustain a force (United States Marine Corps [USMC], 1997). It is grounded in four principle concerns: time, space,

consumption rates, and resources. Successful logistics occurs when both resources are maintained in balance with consumption rates, and time and space are managed to effectively distribute those resources. Therefore, logistics C2 decision making is driven by the allocation of assets to sustain consumption rates across the battle space, and correspondingly training must represent operational actions over time, report resources consumed, and have resources for distribution. This makes the use of live units to support logistics C2 training a near impossible task. This is generally due to three primary reasons: cost, secondary effects, and priority of training. First, the cost of distributing resources in mass across a space is disproportional to the training value gained by a logistics C2 watch floor. Second, using live units gives no room for error. If the logistics C2 training audience fails, the secondary effects degrade the operational units. Finally, due to the nature of military organization, ground units should and will always take priority; thus, once a ground unit is introduced, logistics is no longer the primary focus of the training. Ultimately, live logistics C2 training is only appropriate as a secondary benefit in support of larger scale training.

The solution which the DoD is currently utilizing is simulation. The logistics C2 watch floor can be isolated by using simulation to represent operational forces, resources being distributed, and the assets being allocated. This allows logistics C2 to remain the training priority, and work across the principle concerns without physical consequence for mistakes. Additionally, simulation drastically reduces the cost of training. However, the question still remains which simulation is most capable of supporting the training objective? Is there an existing simulation that can be utilized ubiquitously within the logistics community? Does one simulation provide better training for operational logistics and another simulation provide better training for tactical logistics? If simulation is the tool box, what tool goes with each type of logistics training?

C. RESEARCH QUESTIONS

- How can constructive simulation and/or federates be utilized to increase the capability and efficacy of logistics C2 training?

- What is the primary shortfall or limitation in current logistics C2 training design and execution?
- How can existing DoD constructive simulation be utilized to mitigate the primary shortfall of logistics C2 training design and execution?
- Are different existing DoD constructive simulations better for different levels of logistics C2 training, or is there a constructive simulation that meets the needs ubiquitously across the logistics community?
- Can constructive simulation be used to simultaneously train echelons of logistics C2 staffs both vertically and laterally?

D. REQUIREMENT FOR REALISTIC LOGISTICS C2 TRAINING

1. Future of the Marine Corps

Logistics is the primary limiting factor of maneuver warfare (USMC, 1997). This fact becomes increasingly relevant as the Marine Corps shapes itself adapting to the future threat. The 21st century fight consist of sea based sustainment for widely distributed, small, agile units which are task organized for specific missions (CMC, 2014). In this dynamic environment the use of “iron mountains of supply and lakes of liquid fuel” (CMC, 2016b p. 9) present an ideal target for a peer adversary. Logistics then becomes the allocation of limited resources rapidly deployed and prioritized to support the operating unit. Therefore, the logistics community must continue to advance integration with the Navy, increase the use of dynamic small unit teams to push logistics as far forward as possible, and foster transparent communication both laterally and vertically across MAGTF logistics elements to prioritize resources (CMC, 2016b). In summary, logistics C2 decision makers at all levels of leadership must be creative problem solvers with a full understanding of not only their organic and adjacent assets, but also the operational scheme of maneuver to ensure distribution of logistics does not hinder operational momentum.

Adhering to the Marine Corps philosophy of “train as you fight” logistics C2 staffs must be trained to operate across the range of military operations employing all aspects of

logistics. Mentally stressful training utilizing simulation to increase repetition must become the precursor to live large scale training (CMC, 2016a). To accomplish this the simulation used to stimulate decision making must represent the appropriate level of logistical fidelity to support the training audience. Logistics data must be realistic to mirror what will happen on the battlefield.

2. Marine Corps Logistics Operations Group

Marine Corps Logistics Operations Group (MCLOG) is the primary provider for logistics C2 training in the Marine Corps with the mission:

MCLOG provides standardized, advanced individual training in MAGTF logistics operations and unit readiness planning at the Battalion and Regimental levels, conducts Battle Staff Training, facilitates logistics education and manages doctrine, training standards, tactics and institutional training programs in order to enhance combat preparation and performance of Logistics Combat Element units in MAGTF operations. (MCLOG, 2019, para1)

In response to CMC guidance concerning the future of the Marine Corps, MCLOG has started the process of examining how to adapt logistics C2 training to meet future needs.

This research supports three areas of interest for MCLOG: analyzing the logistics capability of existing DoD constructive simulations, the potential for simultaneous training across MAGTF logistics units utilizing constructive simulation, and the benefits of simulation interoperability to support training. Due to continual updates and modifications of constructive simulations across the DoD, training providers must continually conduct analyses to ensure systems utilized are best suited to accomplish the objective. These analyses extend capability by incorporating the training tools used by sister services. Simultaneous training of echelons of command offers the potential to incorporate tactical and operational decision making which is vital in a limited resource environment. System interoperability between constructive simulations presents the opportunity to increase training objectives incorporating adjacent units into the training audience. These three areas advance the effective use of constructive simulation for logistic C2 training and the overall readiness of logistics capability across the Marine Corps.

E. RESEARCH ORGANIZATION

This study was conducted in five segments: understanding the problem space, developing analysis methodology, lab development, conducting analysis, and drawing conclusions.

1. Understanding the Problem Space

Marine Corps doctrine presents a comprehensive philosophy of logistics which can be adapted to fit any unique situation by decision makers. While doctrine lays the foundation for the execution of logistics, it does not impede the decision maker's ability to think critically and solve problems. Logistics doctrine breaks down the spectrum of logistics operations in an organized fashion which outlines a common language for all logistics communities. This gives great flexibility to the training design of logistics C2. MCLOG has developed a training design which remains versatile, fitting across the spectrum of logistics operations and continually utilizing research as a catalyst for training development. The master's thesis *Integrating Training Simulations and Logistics Information Technology Systems in Support of Marine Corps Simulation-Supported Exercises* (Conard, 2018) was the first step in addressing the research questions proposed. Conard conducted an informal investigation to establish a theoretical course of action to update the use of constructive simulation in the MCLOG training design. The 2018 findings are continued in this research through formal analysis by conducting physical tests on the systems to determine logistics capability.

2. Analysis Methodology

Gap analysis was used as the foundation for this methodology. Two aspects of the five configurations outlined in the purpose section were taken into consideration for analysis: the quality of logistical data and the potential for integration into existing infrastructure. To ensure maximum consistency a scripted tactical scenario was developed to standardize the force layout and scheme of maneuver across the experiments. The script was then played out in each configuration to collect the resulting logistics data which was assessed in terms of utility in logistics C2 training. By developing a simple combat engagement scenario, the general training design used by MCLOG was mirrored and most

of the functional areas of logistics were included. The hardware setup and interoperability capabilities with operational C2 systems were addressed, ensuring any recommended changes to training design can be integrated with minimal interference to the training cycle.

3. Lab Development

A closed networked lab was established to conduct this research at the Modeling and Virtual Environments Institute, Naval Postgraduate School. The creation of this lab gave unique insight into the requirements for acquiring, installing, and networking these simulations. A single computer running the operating system (OS) Red Hat Linux 6.9 was used to run JCATS. A Dell T640 Server running Red Hat Enterprise Linux (RHEL) 7.5 OS maintained the Model System Control (MSC), Model Application Network (MAN), and Combat Analysis and Review Toolkit (CART) components of MTWS, and were controlled by the user from a virtual machine. The MTWS client, Model Display System (MDS) workstation, was installed on a computer running Windows 10 OS. JDLM client and server applications were installed on a single computer running Windows 10 OS. For federation capability the High Level Architecture (HLA) Listener application for JDLM was installed on a computer running Red Hat Linux 6.9. All computers were networked via a Cisco R2960 switch, Figure 1.

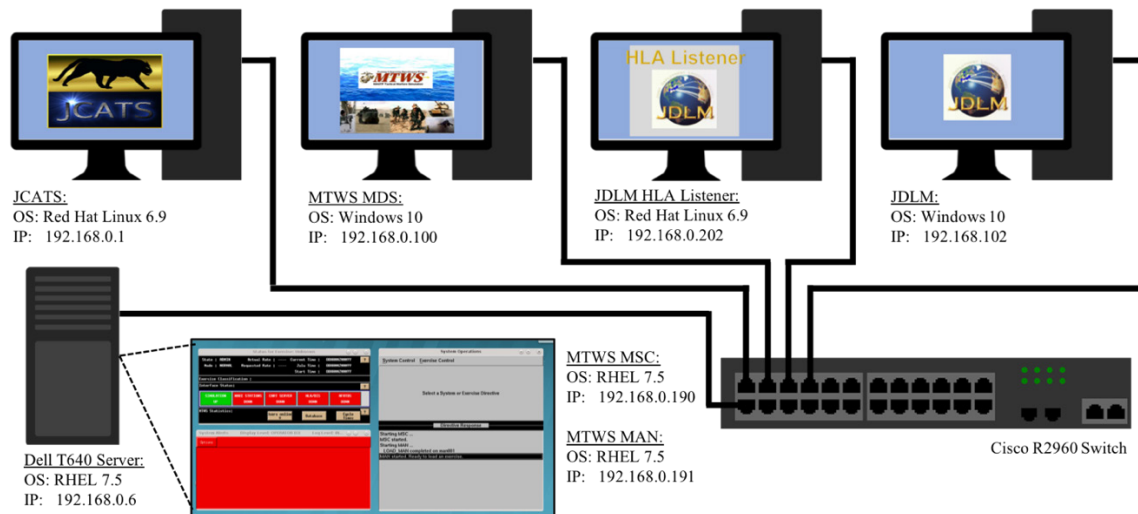


Figure 1. Constructive simulation lab configuration diagram

F. DEFINITIONS

- **Aggregate level simulation.** A simulation designed to consolidate entities at a specific aggregation level, or unit echelon. Interactions between units are adjudicated using the capability of the unit as a whole, and not through the capability of each individual entity within the unit. Furthermore, computation is handled at the level of aggregation and not by computing interaction for each individual entity. Aggregate level simulations support high level training by decreasing the computation requirements for vast numbers of entities, and condensing those entities into manageable units.
- **Aggregation.** “The ability to group entities while preserving the collective effects of entity behavior and interaction while grouped” (DoD, 2011, p 71).
- **Combat model.** A model and/or simulation designed specifically to represent combat. Combat models prioritize computing power to the adjudication of combat engagements between objects, and providing a realistic outcome of battle for the user.
- **Constructive simulation.** “A constructive simulation includes simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes. A constructive simulation is a computer program” (DoD, 2011, p. 85).
- **Entity.** “Any component in a system that requires explicit representation in a model. Entities possess attributes denoting specific properties” (DoD, 2011, p. 98). In constructive simulations entities are considered any individual model required to form the simulation environment such as a person, a weapon system, or a piece of equipment.
- **Entity level simulation.** A simulation designed to represent entities as individual components. Entity level simulations can be adjusted to display

entities as aggregations, however, all computation to adjudicate interactions is handled for each entity.

- **Federate.** Any system sending and/or receiving information across a federation is considered a federate. “The term ‘federate’ is used rather than ‘simulation’ because some federates may perform non-simulation functions” (Morse, 2015). Federates include, but are not limited to, constructive simulation, C2 systems, input from live units, and management systems (DoD, 2011). For the purpose of this research, a federate is another term for the constructive simulation when it is connected and operating with another constructive simulation.
- **Federation.** “In High Level Architecture, named set of interacting federate applications, a common object model, and software infrastructure through which they communicate that are used as a whole to achieve some specific objective” (DoD, 2011, p. 102). Federations consist of federates, a federated object model (FOM), and run-time infrastructure (RTI), and are used to combine the strengths of various systems increasing capability to include a diverse training audience or operational objective (Morse, 2015).
- **Federated object model.** The FOM establishes a common language to facilitate communication between the federates and the RTI, allowing the RTI to pass information across the entire federation (Dahmann, Kuhl, & Weatherly, 2000). “The FOM describes the structure and data types for the information to be exchanged, but not the actual data. The FOM is specified using an XML schema” (Morse, 2015, p. 3).
- **High Level Architecture.** HLA establishes standard rules for creating a federation. The HLA standard connects systems through a separate interface preventing direct contact between systems and providing the means for systems to connect and disconnect without impacting the entire

federation (Morse, 2015). For the purposes of this research HLA is the standard used to establish the federations outlined in Chapter V.

- **Logistics Model.** A model and/or simulation designed specifically to represent logistics. Logistics models prioritize computing power to the development of logistical data and response.
- **Object Model Template (OMT).** “The OMT prescribes the allowed structure of every FOM. The OMT is the meta-model for all FOMs” (Dahmann et al., 2000, p. 3).
- **Run-time infrastructure.** The software that acts as an intermediary between federates allowing communication to occur across the federation. Each federate maintains a single point of contact with the RTI and utilizes only the services of the RTI that are of specific interest (Dahmann et al., 2000). This allows the federates to pass data concerning objects and interactions to the RTI as dictated by the FOM, while only receiving information from the RTI important to the individual federate.

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II. MARINE CORPS LOGISTICS AND C2 TRAINING

The fidelity of logistics data in a constructive simulation is the primary factor in determining the utility of a system to aid in logistics C2 training. This statement is supported both through a comprehensive understanding of Marine Corps logistics and prior research utilizing the fidelity of logistics data as a base for analysis. Furthermore, shortfalls in current training practices stem from difficulties in providing decision makers with realistic logistics data. The following covers basic Marine Corps logistics doctrine, current training practices used by MCLOG for logistics C2 training, and prior research in the uses of constructive simulation in logistics C2 training. This provides the context necessary to establish an analysis methodology in the next chapter.

The ability to solve problems is the foundation of Marine Corps logistics. Across the spectrum of logistics operations there remains a constant problem in the ability to sustain consumption rates across the battle space. Dynamic critical thought at every level of leadership throughout the logistics element is the solution. Therefore, proper training in logistics C2 requires every member of the staff to be challenged mentally. During training, the consumption rates must force difficult decisions which stress leaders to make prioritized allocations of limited resources over large spaces. To ensure logistics does not inhibit maneuver, training must push the boundaries of distribution to prevent the development a “false sense of security in the minds of supported commanders” (USMC, 1997, p. 108) and in the logistics staffs themselves.

A. MARINE CORPS LOGISTICS

“Marine Corps’ logistics mission, at all command and support levels, is to generate MAGTFs that are rapidly deployable, self-reliant, self-sustaining, and flexible and that can rapidly reconstitute” (USMC, 2016a, p. 1-1). This means that the purpose for operations at all levels of logistics is the support of tactical level operation. With a unified focus, Marine Corps doctrine establishes a basic philosophy of logistics that sets the foundation for all decision makers. All Marine Corps logistics contain a similar process, functional elements, and principles.

The basic process is a cycle of four stages: acquisition, distribution, sustainment, and disposition (USMC, 1997). To execute this cycle logistics operations contain two elements: a distribution system and C2 (USMC, 1997). The distribution system consists of a base which receives and stores resources and a distribution procedure which manages those resources. Logistics C2, discussed in detail below, regulates the logistics process based on quantitative logistics data collected from the operating forces. When establishing these elements and executing the logistics process, seven principles of logistics support are considered: responsiveness, simplicity, flexibility, economy, attainability, sustainability, and survivability (USMC, 2016a). This is the starting block for all logistics decision points and provides the basic layout of logistics allowing decision makers to adapt to circumstance.

1. Organization of Marine Corps Logistics

Marine Corps logistics is organized to mirror the levels of war: strategic logistics, operational logistics, and tactical logistics. These levels form the logistics continuum, Figure 2, shows the cycle of tactical operations creating requirements and national resources filling those requirements.

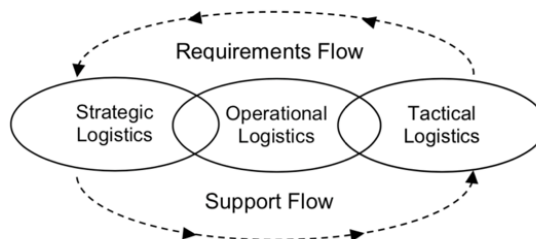


Figure 2. Logistics continuum. Source: USMC (2016b, p.1-2).

Strategic logistics is the national perspective of converting the nations resources into military power. At this level the areas of interest are acquisitions, recruiting, and sustainment of permanent bases (USMC, 1997). Strategic logistics is focused on both the advancement of the Marine Corps to address the future fight, and maintaining the overall

force to sustain current worldwide operations. Operational logistics is the theater or campaign perspective providing a transfer point between national resources and the individual operations occurring within geographical regions (USMC, 1997). The coordination and apportionment of resources across services in theater is controlled at the operational level to resolve the requirements of tactical operations. (USMC, 2016a). Tactical logistics consist of the logistics necessary to directly support an operational scheme of maneuver (USMC, 2016a). MAGTF operations reside at the tactical level and, as a result, Marine Corp logistics predominately operate within the tactical logistics realm corresponding to the logistics mission (USMC, 2016a).

2. Tactical Logistics

Tactical logistics is driven by quantitative consumption rates and executed by adaptable distribution processes. This level of logistics is organized into six functional areas: supply, maintenance, transportation, general engineering, health services, and services (USMC, 2016b). These areas are further divided to cover the spectrum of logistics operations and define a method of management, Table 1. Logistics services, resources, and data are classified into these functional areas, which guide the structural organization and the administrative responsibility of a logistics unit. Successful tactical logistics is the ability to effectively distribute these functions in support of MAGTF operations.

Table 1. Functions and Sub-functions of Tactical Logistics. Source: USMC (2016b, p. 1-10).

Supply	Maintenance	Transportation
• Determination of requirements • Requisition authority • Storage • Procurement • Distribution • Salvage • Disposal	• Inspection and classification • Servicing and repair • Modification • Rebuilding and overhaul • Reclamation • Recovery and evacuation	• Embarkation and landing support • Port and terminal operations • Motor transport • Aerial delivery • Freight and passenger transportation • Material handling equipment
General Engineering	Health Services Support	Services
• Engineer reconnaissance • Bridging • Horizontal/vertical construction • Facilities maintenance • Demolition/obstacle removal • Explosive ordnance disposal • Receive, store, and distribute bulk fuel • Water production and storage • Power generation and distribution	• Casualty management • Force health protection and prevention • Medical logistics • Medical command and control • Medical stability operations	Command: • Personnel administration • Religious ministries support • Financial management • Communications • Billeting • Food service and subsistence support • band • Morale, eelfare and recreation CSS: • Disbursing • Postal • MCCC exchange services • Security • Legal services • Civil affairs • Mortuary affairs • Contracting

The MAGTF is utilized by the Marine Corps as the structure for expeditionary operation. While the scale and detailed organization of a MAGTF is flexible to meet specific mission sets, every MAGTF contains four base elements: the command element (CE), the aviation combat element (ACE), the ground combat element (GCE), and the logistics combat element (LCE) (USMC Concepts & Programs, 2019a). The CE, ACE, and GCE contain limited organic logistics capability necessary to operate. The LCE is responsible for providing in depth capability for the entire MAGTF spanning the functional areas (USMC ,2016b). Lateral relationships between the logistics components of the GCE and ACE with the LCE are essential to overall success of the MAGTF, Figure 3. Clear lines of communication to pass logistics data between the MAGTF elements allow the proper distribution of logistical functions to meet the need of a dynamic operating force.

The vertical relationship between the LCE and logistics components of the ACE and GCE with the CE logistics component is equally as important. This relationship engages the link between operational and tactical logistics while also establishing required prioritization and allocation realignment to remain self-sufficient. Ultimately, the success of the MAGTF depends on the ability of decision makers within logistics C2 to collect quantitative logistics data, determine consumption rates, process those consumption rates, and effectively respond.

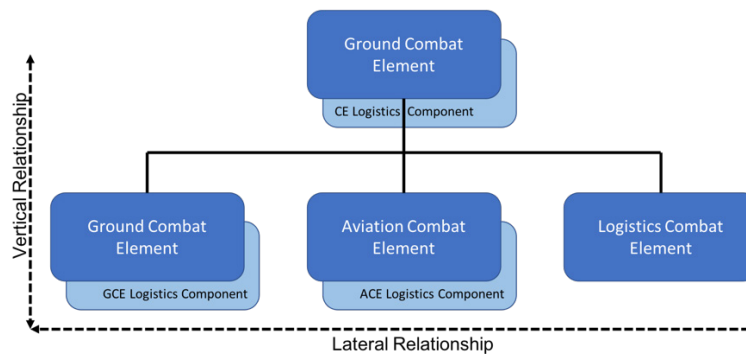


Figure 3. MAGTF structure and logistics relationships

3. Logistics Command and Control

Logistics C2 is based on quantitative data collection and management. The ability of a logistics C2 staff to efficiently receive, process, and respond to numerical data directly corresponds to the effectiveness of the logistics unit to support an operation. Decisions made within logistics C2 are based on an operational picture of the battle space developed by the overarching scheme of maneuver, location of operating units, and what those units possess and require. Logistics commanders use that operational picture to allocate resources, prioritize assets, and distribute/preposition logistics capability. The fidelity of logistics data received by the C2 staff dictates the clarity of the operational picture, thus, detailed logistics data lessens uncertainty which empowers all decision makers.

Command operation centers (COC) are developed by logistics units to execute C2 capability. A standard operating procedure (SOP), unique to each unit, outlines how the

COC functions to include communication methods, procedure for logistics data management, the specific staff required to oversee each functional area, and the delegation of authority to control operations. Furthermore, the SOP provides redundancy in procedure establishing both electronic and analog methods for C2. The Marine Corps maintains programs expressly for the purpose of logistics management, these programs are referred to as MAGTF Logistics Support Systems (MLS2) and are identified in Marine Corp Bulletin 4018. Every logistics unit uses various MLS2 to best meet the mission sets of that unit. Tracking the movement and location of units across the battle space is done electronically by a C2 system. Analog procedures are conducted simultaneously with electronic methods through map tracking and hard copy record as defined by the SOP. Logistics C2 training operates with the assumption that digital communication will fail, and analog methods are required to prevent hindering operational maneuver.

For a COC to run effectively, every person must not only understand their individual role but how that role contributes to the efficacy of the COC as a whole. Furthermore, for a COC to succeed, decision makers must understand what resources are available and how the distribution of those resources affects both the immediate and future requirements. To achieve this, SOPs must be tested and refined through high repetition training which challenges every member of the COC. Having the flexibility to fail in training allows decision makers to stretch logistics capability, and see the effects of implementing logistics functions in different ways to support operations.

B. CURRENT MCLOG TRAINING DESIGN

MCLOG implements a human centric training design which empowers every member of a logistics COC to exercise decision making. The focal point of MCLOG logistic C2 training is the cohesion of personnel within an LCE COC to effectively coordinate logistical support across a MAGTF (MCLOG, 2019). To achieve this MCLOG creates an artificial environment depicting a realistic MAGTF operation for the training audience to support. The environment is developed within a constructive simulation, specifically MTWS, and an operational picture is established by the training audience using

roll players, MLS2, and C2 systems. MCLOG's training design can be broken into two phases: training preparation and planning, and training execution.

1. Training Preparation and Planning

MCLOG formulates each training operation to achieve unit specified objectives. These objectives are referenced throughout planning and execution to ensure all aspects of training support the accomplishment of those objectives. A master scenario event list (MSEL) is developed to establish the operational actions required to exercise the training objectives to proficiency. The MSEL consists of chronological events that take place during execution with each event containing general information concerning the logistics support requirement, Figure 4.

Timeline	9:00:00 AM	09:30+/-	10:00	10:30+/-	11:00+/-	11:30+/-
Event Number	4228	4228	4101	4101	4528	4222
Event	23rd Marines Request	Convoy hit by Rockslide	Bridge Collapse	Blood Lost	MOPP Level Change	Norovirus infects DHS
Inject Unit (Role player)	1st Maint BN	CLR-1	Eng CO QySgt Foreman	Surgical CO LTJG Williams	MEF G-4	1st TSB/ESB Subordinate CO
Convoy # or Unit	CLR-15	1st MLG	7th ESB	1st MED BN	1st MLG	1st MLG/7th ESB
Inject Method	CLC2S / Email	Chat	Verbal	Verbal	Email	CHAT
System (S6)	CLC2S / Email	Chat	Verbal	Verbal	Email	CHAT
Description	23rd Marines request a MRE resupply to CSSD in Miramar. CSSD cannot support request and needs higher to respond to this request.	Rock slide on Hwy 62 takes out two vehicles in a CLB-1 convoy. The road still has one lane open.	ESB Marines arrive to remove rubble. Bridge collapses. Requires Bridge CO to respond with temporary bridge emplacement.	A Surgical Co reports that both blood storage units are not working.	MEF directs increasing MOPP level from 0 to 2.	Norovirus begins infecting Marines at 1st TSB and 7th ESB

Figure 4. MSEL excerpt used by MCLOG designed for a training exercise for 1st Marine Logistics Group

Following the development of a MSEL, a detailed tactical scenario is designed to provide operational context. The tactical scenario forms a script for the entire MAGTF operation including enemy units. The purpose of the tactical scenario is to create a comprehensive understanding of the battle space for the roll players and training audience, and to act as a blueprint for the development of the artificial environment.

The tactical scenario is populated in MTWS and unit specific MLS2 through starting exercise (STARTEX) data. To process STARTEX data every system requires a unique file format. As STARTEX data is frequently modified prior to an exercise, maintaining consistent content across the required file formats is extremely difficult and labor intensive. MCLOG developed a Batch File Generator (BFG) to ensure consistency across technical systems. The BFG is designed for compatibility with MTWS batch files, JDLM prototypes, and the Common Logistics Command and Control System (CLC2S) files. (Conard, 2018). Following the initialization of the tactical scenario in the technical systems it is tested.

MCLOG conducts an initial playout of the tactical scenario for scenario refinement, confirming the technical operation of MTWS, MLS2, and C2 systems, and collects logistics data. Playing out the scenario allows the primary training support staff to fully understand the script and ensure the MSEL is accomplished to adequately meet the training objectives. Adjustments are made to the scenario and MTWS if there are issues with the logical order of operation or simulation behavior. Network connectivity at each client station is checked during the initial playout to ensure technical aspects are functioning properly. As the scenario is rehearsed, logistics data from MTWS is collected and refined to the required fidelity, in accordance with the MSEL, and used to create electronic logistics request in the MLS2 used by the unit. By creating the request in advance, it saves time for roll players during the exercise, and further confirms logistics operations support the initial training objectives. Furthermore, any virtual imaging is created to support the tactical scenario using a virtual reality system. This includes aerial reconnaissance, unmanned aerial vehicle video feed, or any other type of imagery required. Following the tactical scenario refinement, technical checks, and logistics data collection the planning and preparation phase is complete and the MCLOG staff is ready to receive the training audience.

2. Training Execution

Training execution begins when the training audience arrives and establishes a physical COC. The infrastructure in place for training contains four components: system

control stations, exercise control, roll players stations, and the COC, Figure 5. The analyses conducted in this research use the current hardware layout as a baseline to establish the ease of integration of individual or federated constructive simulations into training design, discussed in detail in Chapter III.

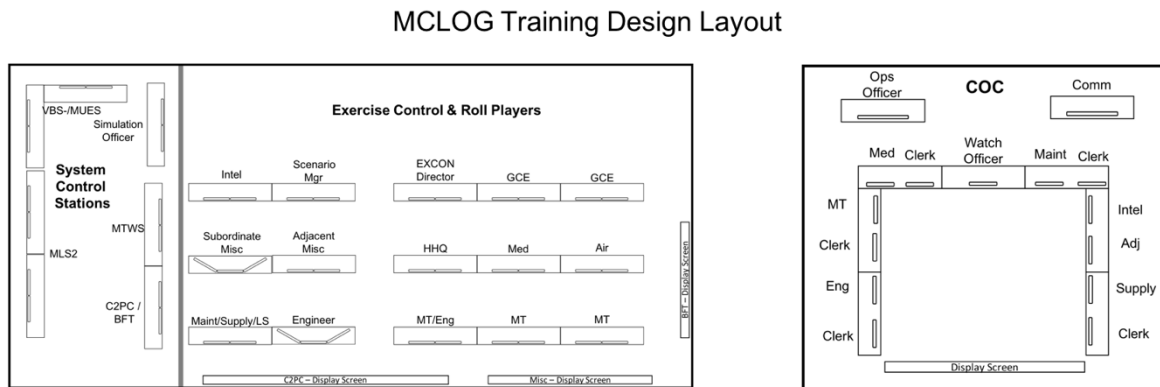


Figure 5. Example of MCLOG training design physical layout of workstations

The system control stations, exercise control, and roll player stations are collocated for ease of communication and the COC is established at a separate location. The exercise control component manages the overall execution of training and works with the Commanding Officer and/or Operations Officer of the training audience to adjust training as needed during execution. Roll players are assigned specific units to control and monitor during the exercise. The systems control stations are responsible for the technical aspect of training, ensuring the network remains open, monitoring the constructive simulation, and providing virtual visual feed as necessary. The COC is laid out in accordance with the unit SOP and set up for both analog and electronic C2 capability.

A common network is used to distribute the systems to the work stations, Figure 6.

MCLOG Training Design Network Diagram

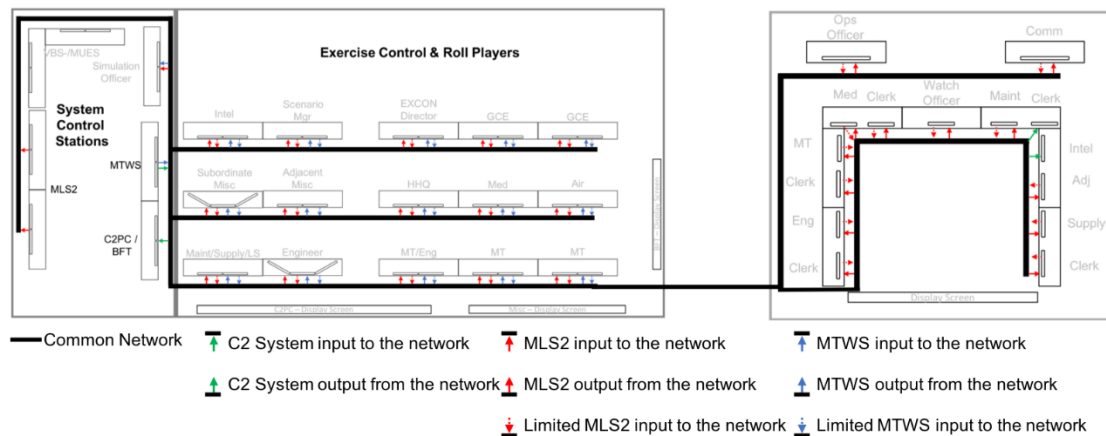


Figure 6. MCLOG current network distribution

The MLS2 used for the exercise, most commonly CLC2S, is accessed by roll player stations and monitored by the system control station through the common network. Roll players send and monitor logistics requests throughout the exercise using MLS2, email, voice, radio, chat, and any other methods of communication defined by the MSEL. MTWS is the primary constructive simulation used by MCLOG. The MTWS server controls all client stations used by roll players, is monitored by the system control station, and pushes information to the C2 systems through the common network. Roll players provide limited input to the MTWS scenario controlling only the units specifically represented. MTWS is utilized only to stimulate the C2 systems during execution. The logistics data collected from MTWS and MLS2 logistics request created during the planning phase are used to drive logistics operation throughout execution in accordance with the MSEL. The two C2 systems primarily used by MCLOG and interoperable with MTWS are the Command and Control Personal Computer (C2PC) and Blue Force Tracker (BFT). MTWS contains organic interfaces for interoperability with C2 systems (Cole Engineering Services Incorporated [CESI], 2018). An interface feeds into the Global Command and Control System - Tactical Combat Operations (GCCS-TCO) which acts a server controlling C2PC and BFT clients, Figure 7 (USMC Concepts and Programs, 2019b).

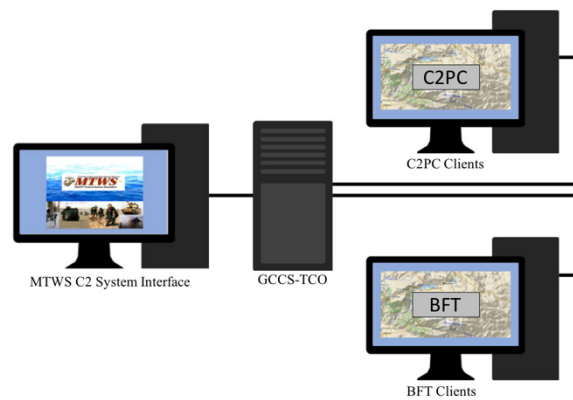


Figure 7. MCLOG C2 system interface configuration

The COC connects to the common network to operate the MLS2 and monitor C2PC and BFT. However, the training audience does not have access to MTWS during the exercise. This setup provides the COC with realistic network capability and the detachment from operational unit representatives necessary for realistic communication methods used to create the operational picture.

Training exercises are typically conducted over a five day period. Day one consists of set up, initial briefing, and introductions. Days two through four are full training days working through the tactical scenario. Day five concludes the tactical scenario providing a detailed after action brief and report. The execution days are designed to provide interactive feedback and constructive review between the training audience and the evaluators. The ongoing feedback gives individual attention to every person working within the COC and keeps the focus on decision makers at every level. Both electronic and analog procedures are exercised during the training to examine all aspects of the unit SOP for refinement. To ensure the original training objectives are met, the exercise is flexible during execution through the training audience leadership and exercise control staff. Following the exercise, the after action covers every aspect of the COC promoting a dialogue from the clerk level through senior leadership. This style of after action is designed to reinforce the importance of decision making at every level prior to concluding the training exercise.

3. Training Limitations

The primary limitation on training efficiency is the use of MTWS as the primary constructive simulation. MTWS is both cumbersome for planning and underutilized during execution. The fidelity of logistics data is minimal in MTWS beyond food, water, fuel, and ammunition (Conard 2018). This creates the requirement for the training support staff to refine logistics data increasing fidelity to meet the MSEL and wasting man hours. The limited capability also constrains the stress that can be applied on a logistics COC, as the default logistics data is considered routine operation. During execution the limitation of MTWS logistics data confines the uses of simulation to movement tracking stimulating the C2 systems. As a result, the flexibility of training during execution is restricted because any adaptation to training requires the training support staff to develop new logistics data and requirements while simultaneously continuing to execute the tactical scenario.

Increasing the fidelity of logistics data within the constructive simulation decreases the requirements placed on the staff during planning and increases flexibility during execution. This affords the MCLOG staff the time necessary to stretch logistic distribution fostering complex critical problem solving across the functional areas of logistics.

C. PRIOR RESEARCH

The master's thesis *Integrating Training Simulations and Logistics Information Technology Systems in Support of Marine Corps Simulation-Supported Exercises* (Conard, 2018) conducted the first steps in addressing the effective use of constructive simulation in logistics C2 training. Conard (2018) addressed two research questions specifically concerning logistics data in constructive simulation:

1. "What are the current capabilities and shortfalls of logistics information produced within MTWS and JDLM?" (p. 2)
2. "What logistics information is passed between MTWS and JDLM through the Joint Live Virtual and Constructive (JLVC) federation?" (Conard, 2018, p. 2)

An informal analysis examined the logistics capabilities of MTWS and JDLM as individual systems, and as a federated system. Conard organized capabilities and limitations of the systems by the level of detail achieved across the subcategories of the six functional areas of tactical logistics, using green to identify full capability, yellow identifying limited capability, and red to identify no capability (Conard, 2018).

Table 2. MTWS logistics capability findings. Source: Conard (2018, p. 80).

Supply				
Class I	MRE	Water (gallons)	UGR	Dimensions
Class III	Petroleum (JP5 gallons)	Oil/lubricants	NIIN	DIMENSIONS
Class IV	Horizontal materials	Vertical Materials	NIIN	DIMENSIONS
Class V	DODIC	Dimensions	Explosive Category	
Class VII	TAMCN	Status	Serial Number	Dimensions
Class VIII	Med. Supplies	Blood	NIIN	Dimensions
Class IX	SECREP	Other Class IX	NIIN	Dimensions
Maintenance				
Inspection/Classification	Inspection Time	Specific Condition	Parts Required	
Repair	Repair Time	Parts Required	Mechanics Required	
Recovery/Evacuation	Recovery	Evacuation	Evacuation Level	
Health Services				
Health Maintenance	Routine Casualty	Disease		
Casualty Collection	CCP	Transportation		
Treatment and Triage	Injury Specifics	Med. Sup. Reqmt.	Med. Pers. Reqmt.	Level of care
Temp. Casualty Holding	Bed spaces	Med. Pers. Reqmt.		
Casualty Evacuation	Ground CASEVAC	Air CASEVAC		
Transportation				
Motor Transport	TAMCN	In Transit Visibility	Weight/Dimension lim.	
Air Delivery	Air Delivery	Weight/Dimensions		
MHE	MHE Operation	TAMCN	Weight lim.	
General Engineering				
Hor./Vert. Construction	Bridge	Road	Runway	Supplies Required
Obstacle Removal	Removal Time	Equipment Required		
EOD	Blown in Place	Equipment Required	Explosives Required	
Other Services				
Personnel Tracking	Name	Status	MOS	ID number
Mortuary Affairs	Evacuation Points			

The logistics capability findings for MTWS as an individual system, Table 2, are limited in comparison to the capability findings for JDLM, Table 3. Conard identifies the logistics capabilities of JDLM as exceeding any other fielded simulation within the DoD. However, the primary limitations of JDLM are the inability to simulate combat and the lack of organic capability to connect to C2PC (Conard, 2018).

Table 3. JDLM logistics capability findings. Source: Conard (2018, p. 92).

Supply				
Class I	MRE	Water (gallons)	UGR	Dimensions
Class III	Petroleum (JP5 gallons)	Oil/lubricants	NIIN	Dimensions
Class IV	Horizontal materials	Vertical Materials	NIIN	Dimensions
Class V	DODIC	Dimensions	Explosive Category	
Class VII	TAMCN	Status	Serial Number	Dimensions
Class VIII	Med. Supplies	Blood	NIIN	Dimensions
Class IX	SECREP	Oth. Class IX	NIIN	Dimensions
Maintenance				
Inspection/Classification	Inspection Time	Specific Condition	Parts Required	
Repair	Repair Time	Parts Required	Mechanics Required	
Recovery/Evacuation	Recovery	Evacuation	Evacuation Level	
Health Services				
Health Maintenance	Routine Casualty	Disease		
Casualty Collection	CCP	Transportation		
Treatment and Triage	Injury Specifics	Med. Sup. Reqmt.	Med. Pers. Reqmt.	Level of care
Temp. Casualty Holding	Bed spaces	Med. Pers. Reqmt.		
Casualty Evacuation	Ground CASEVAC	Air CASEVAC		
Transportation				
Motor Transport	TAMCN	In Transit Visibility	Weight/Dimension lim.	
Air Delivery	Air Delivery	Weight/Dimensions		
MHE	MHE Operation	TAMCN	Weight lim.	
General Engineering				
Hor./Vert. Construction	Bridge	Road	Runway	Supplies Required
Obstacle Removal	Removal Time	Equipment Required		
EOD	Blown in Place	Equipment Required	Explosives Required	
Other Services				
Personnel Tracking	Name	Status	MOS	ID number
Mortuary Affairs	Evacuation Points			

Conard concludes that the federation of MTWS and JDLM through the JLVC federation is the ideal method of simulating logistics data for training. By combining the two simulations JDLM provides the bulk of logistics information while MTWS provides the combat model, general engineering capabilities, and interoperability with Marine Corps C2 systems (Conard, 2018).

These findings coupled with Marine Corps logistics doctrine and MCLOG training limitations reinforce the concept that the fidelity of logistics data in constructive simulation is the primary factor in determining the utility of a system to support logistics C2 training. This will form the foundation of the analysis methodology used in this research to advance Conard's work.

III. ANALYSIS METHODOLOGY

The analysis methodology for this research was custom designed to support the areas of interest established by MCLOG and the specific research questions outlined in Chapter I. Gap analysis provided the organizational structure to examine the current capability of training compared to four alternative uses of constructive simulation. Each configuration was implemented in the MCLOG training design for testing using the current training model as a baseline for comparison. The portion of the MCLOG training procedure used for analysis aligns to the training limitations identified in Chapter II, Figure 8.

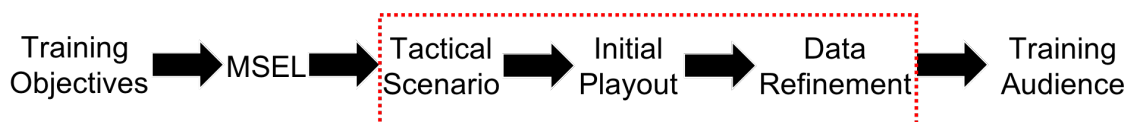


Figure 8. MCLOG training procedure used for analysis

Correspondingly, a tactical scenario was developed and played out in each configuration to support three aspects of analysis: the ease of integration into MCLOG infrastructure, fidelity of logistics data produced, and the potential to support simultaneous training across MAGTF logistics components. The five analyses are categorized as individual or federated constructive simulations and discussed in Chapters IV and V respectively.

The configurations used for analyses along with the standardized tactical scenario, force layout, and analysis format are addressed in the following.

A. CONSTRUCTIVE SIMULATION CONFIGURATIONS

The five configurations were arranged using three constructive simulations. MTWS, JCATS, and JDLM are the primary constructive simulations utilized by the Marine Corps for training, and provide a well-rounded examination of existing DoD simulations, Table 4.

Table 4. Constructive simulation configurations for analyses

Configuration	Aggregate or Entity Based	Combat or Logistics Model
MTWS	Aggregate	Combat
JCATS	Entity	Combat
JDLM	Entity	Logistics
MTWS / JDLM	Aggregate / Entity	Combat / Logistics
JCATS / JDLM	Entity / Entity	Combat / Logistics

The MTWS individual analysis established the baseline and represented an aggregate based combat model designed to support higher echelon training at the Marine Expeditionary Force (MEF) level. In contrast, JCATS as an individual system presented an entity-based combat model designed to support brigade level training and below. The individual analysis of JDLM advanced Conard's (2018) research and represented an entity-based logistics model. Additionally, federations between combat and logistics models were tested in accordance with Conard's (2018) findings. The federated analyses demonstrated the potential for increased capability of logistics training through interoperability.

B. TACTICAL SCENARIO

The tactical scenario was scripted to depict a single combat engagement involving each element of the MAGTF, Figure 9. This provided both a manageable collection of logistics data stretching across four of the six functional areas, and an opportunity to assess the ability of the configuration to support simultaneous training. The four functions of logistics represented during the scenario are: supply, maintenance, health services, and services. The scheme of maneuver consisted of a sequence of events forming a combined arms attack on an objective, listed below.

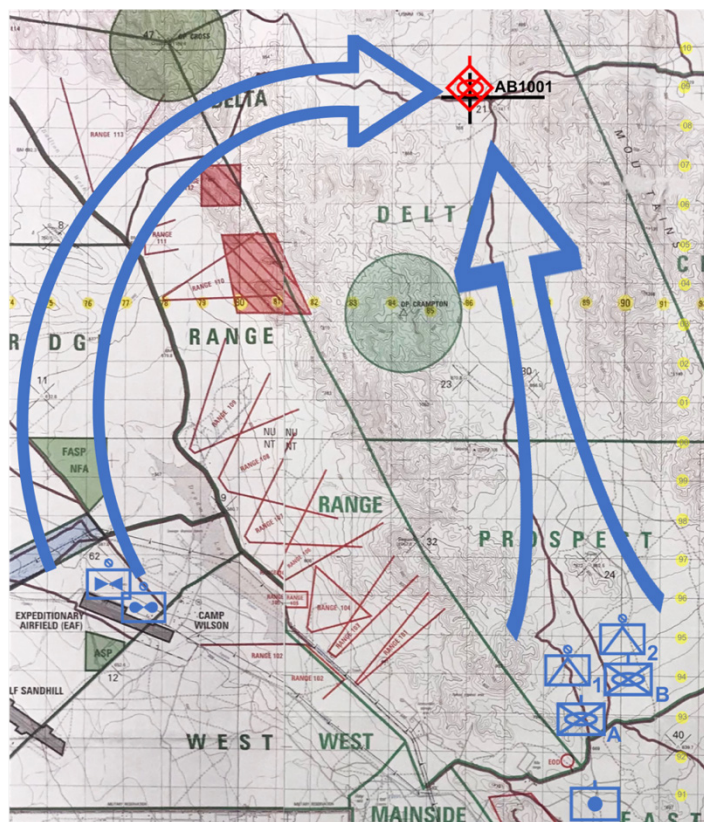


Figure 9. Tactical Scenario Diagram

- Two combined anti-armor teams (CAAT) advance north to provide reconnaissance on enemy forces occupying the objective.
- Two mechanized infantry companies advance north following the CAATs at approximately one-kilometer distance.
- Upon arrival of the CAATs a close air support (CAS) mission is requested, and the Marine Attack Squadron dispatches an aircraft.
- After the CAS mission is complete, indirect fire is requested from the artillery battery and three volleys are fired on the objective.
- The mechanized infantry companies then close with and destroy the enemy.

Incorporating each element of the MAGTF into the scenario triggered a response from each logistics component, listed below. This provided a base case to determine the capability of the configuration to support simultaneous training.

- CE: High levels of casualties and equipment damages require the reallocation and prioritization of resources to ensure the MAGTF maintains operational momentum.
- ACE: Flight time and ordnance expenditure stimulates resource management and maintenance requirements.
- GCE: Movement to contact and attack produced consumption rates, personnel casualties, and maintenance requirements which requires management and communication to the LCE for support.
- LCE: The engagement stimulates operations including supply, maintenance, health services, and services.

The primary purpose of the tactical scenario was to generate logistics data, in accordance with the MCLOG training process. The comparison of the fidelity of logistics data from each alternative configuration to the baseline was the foundation of the analysis. By aligning the configuration with the current training process, it directly addressed the limitation of low fidelity data identified in Chapter II.

C. FORCE LAYOUT STARTEX DATA

The force layout was created using an Order of Battle Service (OBS) extensible markup language (XML) file through the Joint Training Data Service (JTDS), discussed in detail below. This created standard STARTEX data for each configuration. The MAGTF layout consists of the six units involved in the tactical scenario, and four logistics units, Figure 10. The logistics units were included to allow the transfer of logistics requirements from the combat model to JDLM during the federated analyses, discussed further in Chapter V. The opposing force layout consist of a single mechanized infantry company.

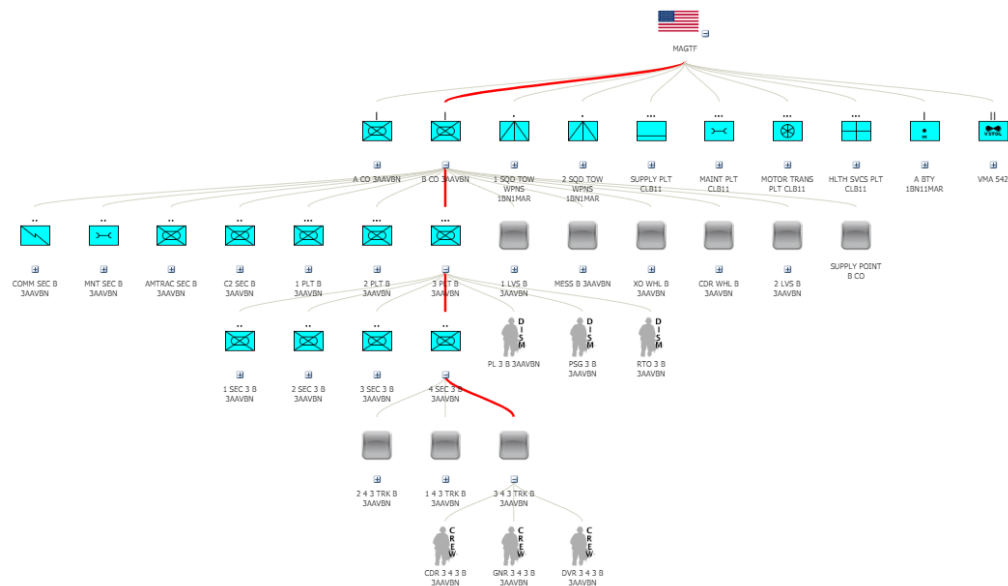


Figure 10. Force layout breakdown

1. Joint Training Data Service

JTDS is a “web-based suite of classified and unclassified authoritative databases and tools” (Joint Staff Deputy Director Joint Training [JS DDJT], 2018, p. 1-1) used for building new data bases specific to training or operational missions. The service is maintained by the Joint Force Development Directorate (J7) to support the JLVC federation by providing a central location for federates to obtain files and software necessary to join the federation. The user accounts and databases in JTDS are regularly updated by the J7 allowing ease of file sharing and development for users worldwide. JTDS contains two components that aid in the standardization of data: OBS and terrain generation services (JS DDJT, 2018). For the purposes of this research only the OBS was utilized to design the force layout.

2. Order of Battle Service

The OBS enables a user to develop custom STARTEX data for an exercise (JS DDJT, 2018). The user defines sides, units, platforms, and lifeforms within the OBS which is exported as an XML file for the simulation to load, Figure 10. These units are custom

built or pulled from a repository and adjusted, Figure 11. The repository is updated routinely to ensure templates are accurate to the unit task organization and table of equipment. Units in the force layout used for analyses were copied from the repository last updated in 2018. Only basic functions of the OBS were utilized for this research to maintain simplicity of design, however, the OBS presents a versatile tool for a user to produce complex scenarios in support of any level of training or operation.

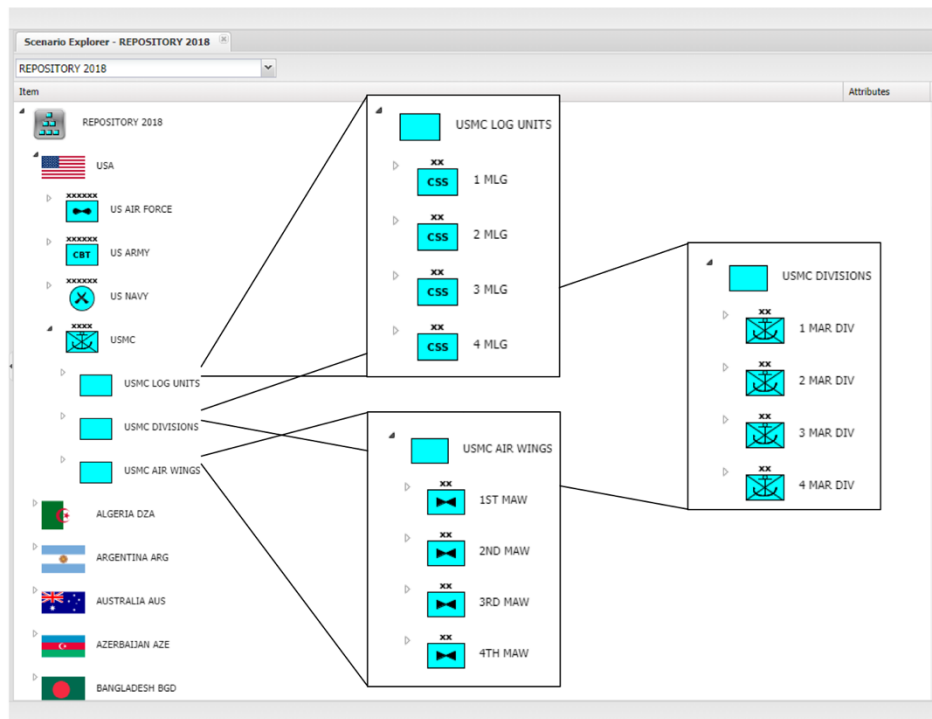


Figure 11. JTDS OBS repository

The force layout contains two sides: MAGTF and opposing force (OPFOR), Figure 12. The MAGTF side was identified as the anchor side, “the side that represents the primary, blue force in the scenario” (JS DDJT, 2018, p. 1-2) from which the combat relationships are based. The OPFOR side was identified as hostile relative to the MAGTF. For units to engage in combat in a constructive simulation the OBS must reflect a hostile relationship.

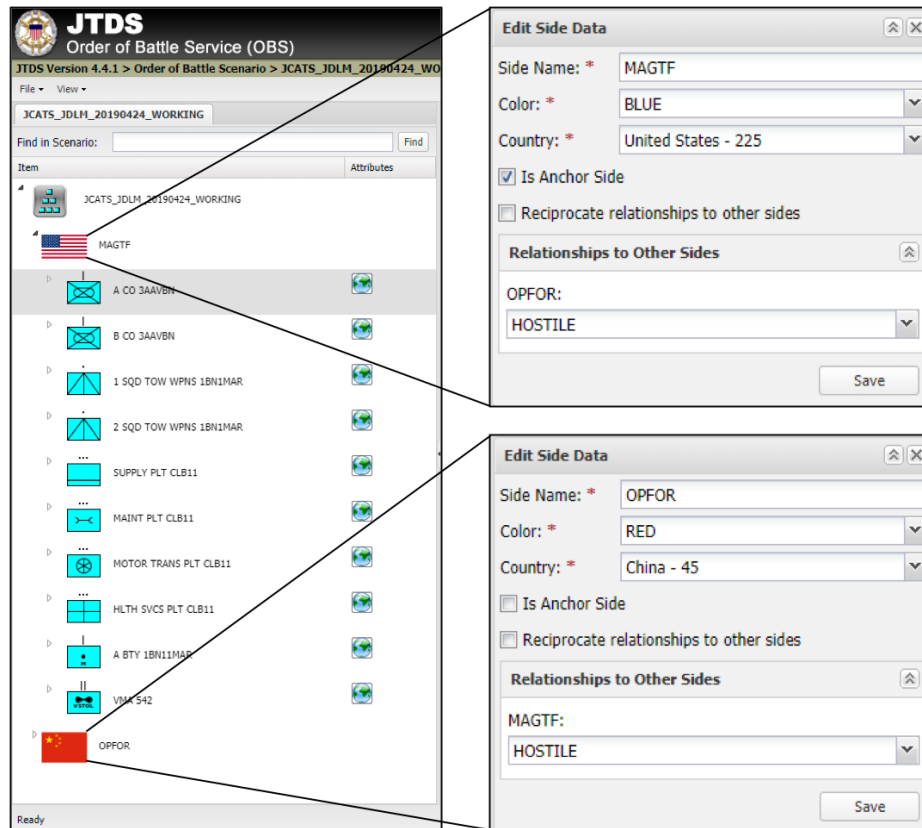


Figure 12. Force layout sides

Each side contains various units identified by the name and the aggregate template set in the unit data, Figure 13. The owning federate, military standard 2525 common warfare symbology, and echelon of the unit are preset according to the template from the repository, and where not adjusted for this scenario. The repository unit instance data assigns supplies, initial unit strength, and whether or not a unit is transferable, inactive, or commandable. The tactical scenario did not require any other functionality of the instance data, and adjusted only the supply levels and simulation specific requirements, discussed in Chapter IV.

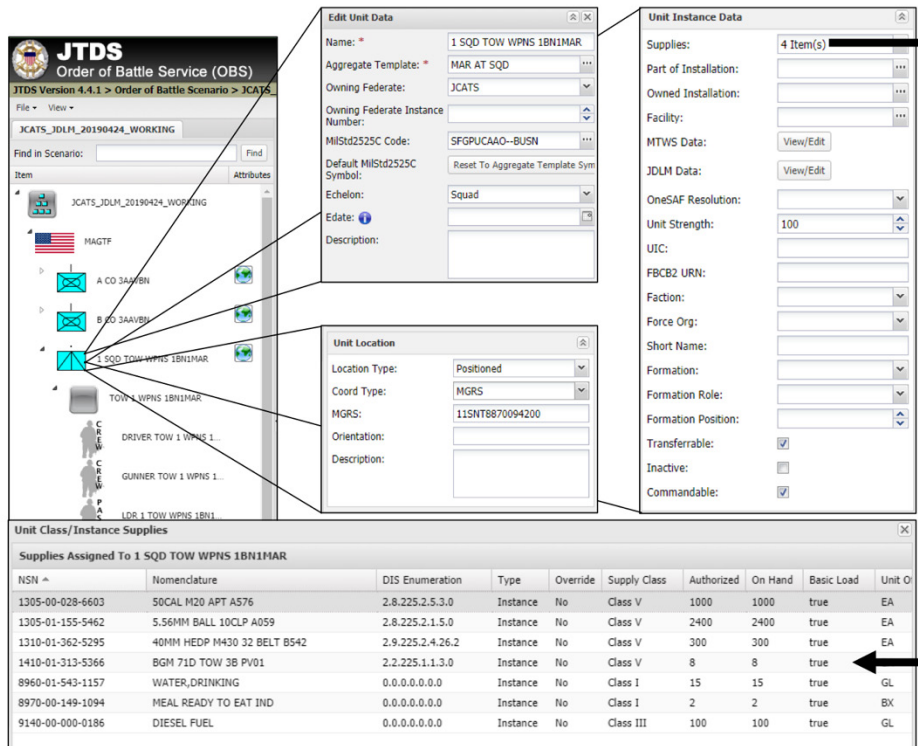


Figure 13. OBS unit

Within each unit platforms and lifeforms are added to reflect the task organization and table of equipment. A platform represents “a major end-item piece of equipment with a primary weapon system, a role, and additional data” (JS DDJT, 2018, p. 6-1). The role, entity class, and table of authorized material control number (TAMCN) of the platform are preset according to the repository and were not altered for this scenario, Figure 14.

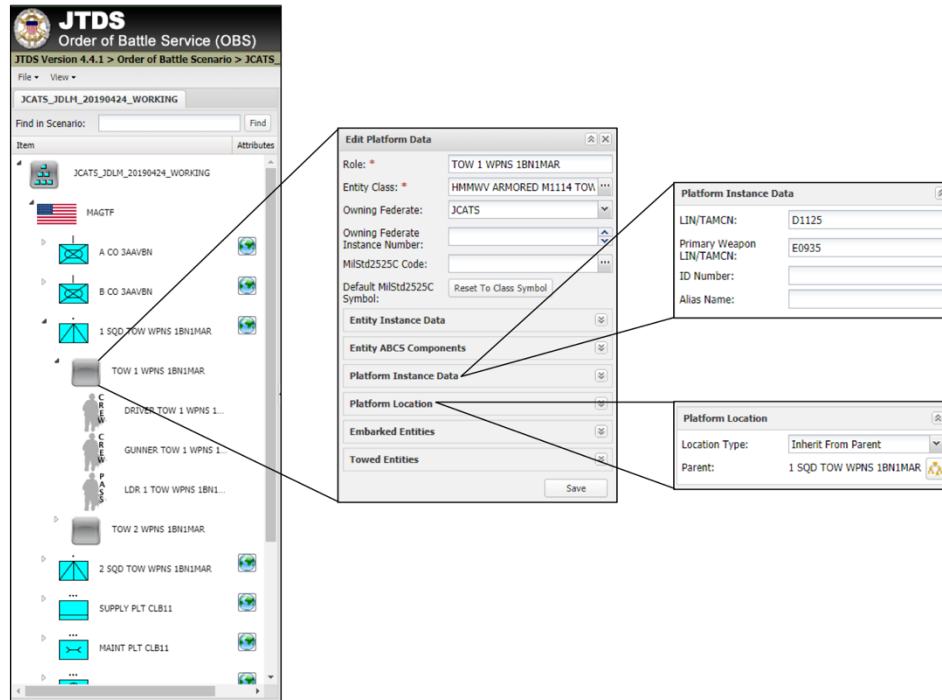


Figure 14. OBS platform

Lifeforms represent personnel and are assigned to either units or platforms. Similar to platforms, lifeforms are assigned a role and an entity class. Lifeform instance data set by the repository includes duty position, occupational code, grade, and mounting status. Additional information includes religion, blood type, and gender which was not added for this scenario, Figure 15.

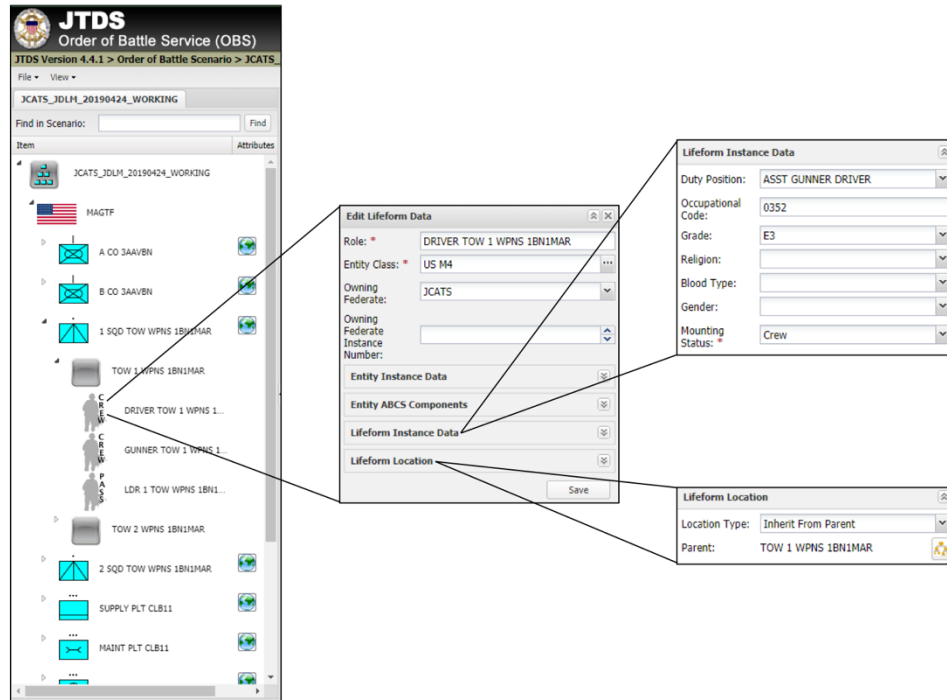


Figure 15. OBS lifeform

D. ANALYSIS FORMAT

For consistency a standard format was developed to organize each individual analysis consisting of five sections and each federated analysis consisting of three sections.

1. Individual Analysis Format

The individual analysis is split into five sections: background, hardware configuration, tactical scenario implementation, logistics capability, and summary of findings.

- Background: This section contains basic information concerning the system, including but not limited to, development purpose, current Marine Corps use, and maintenance/update procedures.
- Simulation Configuration: This section outlines the hardware requirements and generic system configuration used when running the simulation. The

specific configuration established in the constructive simulation lab and used for analysis is described in this section.

- Tactical Scenario Implementation: This section documents how the OBS XML was imported into the system as STARTEX data, and a general overview of how the tactical scenario was played out within the simulation.
- Logistics Data Capability: This section provides information concerning both how the system generates logistics data and where that data is stored for the user. The section is further divided into sub-sections for each logistics function represented in the tactical scenario. Supply capability is described based on the classes of supply represented, Table 5. Maintenance and health services capabilities are described through the level of detail in maintenance/casualty information generated by the system. Services capability is described by the detail of the information generated and system specific functions.
- Summary of Findings: The summary of findings contains a consolidated assessment of the configuration with regards to the three aspects of the analysis: ease of integration into MCLOG existing infrastructure, fidelity of logistics data generated relative to the current configuration, capability to support simultaneous training relative to the current configuration.

Table 5. Classes of supply. Source: USMC (2016b, p. 1-11).

Class	Description	Subclass
I	Subsistence, which includes rations and gratuitous health and welfare items	A–air (in-flight rations), C–operational rations, R–refrigerated subsistence, S–nonrefrigerated, W–ground
II	Minor end items, which include: clothing, individual equipment, tentage, organizational tool sets and tool kits, hand tools, maps, administrative and housekeeping supplies and equipment	A–air, B–troop support materiel, E–general supplies, F–clothing and textiles, H–test, measurement and diagnostic equipment, W–ground, Z–chemical
III	Petroleum, oils, and lubricants, which include petroleum fuels, lubricants, hydraulic and insulating oils, preservatives, liquid and compressed gases, bulk chemical products, coolants, de-icing and antifreeze compounds and the components and additives of such products, and coal	A–air, W–ground (surface), 1–air bulk fuels, 2–air packaged bulk fuels, 3–air packaged petroleum products, 4–ground bulk fuels, 5–ground packaged bulk fuels, 6–ground packaged petroleum, and 7–ground solid fuels
IV	Construction, which includes construction materiel, installed equipment, and all fortification or barrier materiel	T–industrial supplies
V	Ammunition of all types, which includes chemical, biological, radiological, and special weapons, bombs, explosives, mines, fuzes, detonators, pyrotechnics, missiles, rockets, propellants, and other associated items	A–air, L–missiles, N–special weapons, and W–ground
VI	Personal demand items and nonmilitary sales items	
VII	Major end items, which are the final combination of end products assembled and configured in their intended form and ready for use (e.g., launchers, tanks, mobile machine shops, vehicles)	A–air, B–troop support materiel (includes power generators and construction, barrier, bridging, fire-fighting, petroleum, and mapping equipment), D–commercial vehicles, G–electronics, K–tactical vehicles, L–missiles, M–weapons, N–special weapons, O–combat vehicles, Q–marine equipment, U–communication security materiel, W–ground, Y–railway equipment, and Z–chemical
VIII	Medical materiel, which includes supplies to support health service support, force health protection and medical-unique repair parts	A–medical and/or dental materiel and B–blood and blood products
IX	Repair parts, which include components and kits, assemblies, and subassemblies (reparable and nonreparable) required for maintenance support of all equipment	A–air, L–missiles, N–special weapons, T–industrial supplies, W–ground, and Z–chemical
X	Nonmilitary materiel, which includes materiel to support nonmilitary programs (e.g., agriculture, economic development), that is not included in classes I-IX	

2. Federated Analysis Format

The federated analysis format is split into three sections: federation implementation, federation behavior, and summary of findings.

- Federation Implementation: This section contains information outlining the establishment of the federation from a hardware and software

perspective. This includes importing the OBS XML as STARTEX data in each system, federation setting implemented in each system, and the HLA interface used to connect the simulation to the RTI.

- Federation Behavior: This section discusses how the two constructive simulations interacted with each other while the tactical scenario was played out. The section documents observations concerning the transfer of objects, and increases of logistic data from the combat simulation to the logistics simulation.
- Summary of Findings: The summary of findings contains a consolidated assessment of the configuration with regards to the three aspects of the analysis: ease of integration into MCLOG existing infrastructure, fidelity of logistics data generated relative to the current configuration, capability to support simultaneous training relative to the current configuration.

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IV. INDIVIDUAL ANALYSES

A. MTWS ANALYSIS

1. Background

“The MTWS is the Marine Corps only constructive, aggregate resolution simulation system used to support the training of Marine commanders and their battle staffs in MAGTF warfighting principles/concepts and as well as associated command and control procedures” (USMC Concepts & Programs, 2019c, para1). The simulation was designed by CESI as a full member of the J7 JLVC federation to support staff training for battalion level and above, and is maintained as a Marine Corps program of record (CESI, 2019). MTWS is a combat simulation that represents friendly, enemy, and neutral units across land, air, and maritime operations (USMC Concepts & Programs, 2019c). The simulation provides both real time simulation of combat simulation and play back capability to support after action de-briefs. Users throughout the Marine Corps provide simulation behavior feedback for routine updates, making MTWS uniquely suited to represent MAGTF operation.

MTWS is distributed to the Marine Corps for use via MEF Simulation Centers, and formal training centers, most notably the MAGTF Staff Training Program (MSTP). MSTP is responsible for the C2 training of senior commanders and staffs during MAGTF operations, primarily at the MEF and joint level (MSTP, 2019). As the vast majority of MTWS capability is utilized during training exercises, MSTP acts as the primary customer for MTWS conducting testing on beta versions prior to updates, and providing consolidated feedback for future updates. MEF Simulation Centers provide MTWS to support both unit level C2 training, and provide a training facility for formal training events.

2. Simulation Configuration

MTWS consist of three servers and two types of clients, listed below.

- MAN Server: The MAN drives simulation computation. It executes all functions, models, interaction adjudication, and is considered the

“simulation engine” (CESI, 2018, p. 1793). The MAN is also responsible for the single point of contact to the JLVC federation RTI (CESI, 2018).

- MSC Server: The MSC acts as a bridge between the MAN and the simulation users, ensuring data is passed to workstations, reports are generated when solicited, and data is passed to the CART server (CESI, 2018).
- CART Server: The CART collects all data while the simulation is running providing a playback for the users to conduct after action reports and briefs (CESI, 2018).
- MDS Workstations: The MDS is the primary interface for the user to interact with MTWS. The user is able to “define simulated objects and events; and to monitor those objects and events as the simulation progresses” (CESI, 2018, p. 1794). The MDS sends and receives information from the MSC.
- CART Workstations: The CART workstations provide “a read-only, after-action view of an exercise” (CESI, 2018, p. 1794). Data is pulled from the CART server through the MSC to the CART workstation for the user to play back the exercise.

The MSC is the central control of the simulation, Figure 16. Exercises are created, loaded, initialized, and run through the MSC. MDS stations provide input from the user to the MSC, which responds by either providing a solicited report, or passing the information to the MAN for computation. The MAN adjudicates the input from the user and provides an output to the MSC which updates the MDS stations. Simultaneously, the MSC sends data to the CART documenting the exercise and passing required data to C2 systems being utilized. MTWS provides multiple interfaces to operate with C2 systems both directly including C2PC and the Advanced Field Artillery Tactical Data System, and indirectly through systems such as the GCCS-TCO.

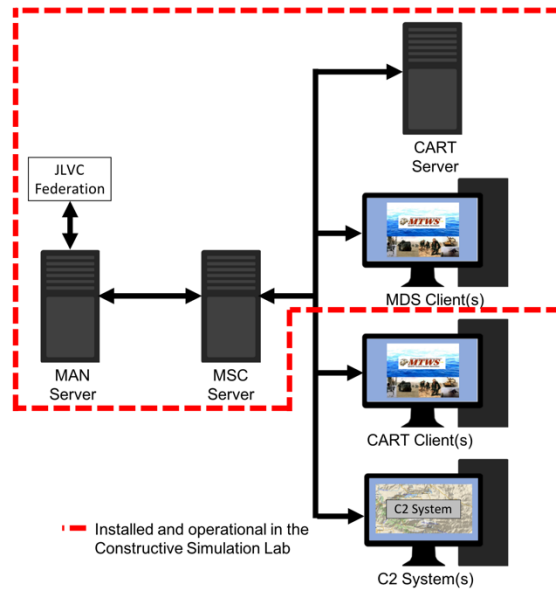


Figure 16. MTWS hardware diagram

Version 38 of MTWS was installed on the MSC, MAN, CART, and MDS in the constructive simulation lab to conduct the analysis, Figure 16. A single server hardware supported the three servers through virtual machines running the OS RHEL 7.5. During install internet protocol (IP) addresses were assigned and linked to create the system network, Figure 1. MDS workstations were installed on ten stations running Windows 10 OS to model the constructive simulation lab after MSTP's infrastructure, however only a single station was used for analysis. Subject matter experts from MSTP were both consulted throughout scenario implementation, and provided in person assistance for the installation of MTWS on site.

3. Tactical Scenario Implementation

The force layout was implemented into MTWS as STARTEX data using a five-step process, detailed below.

1. Alterations to the OBS force layout specific to MTWS.
2. Match the OBS XML to the MTWS parametric data.
3. Convert the OBS XML to a MTWS force layout XML.

4. Load the MTWS force layout XML into the exercise.
5. Initialize and run the exercise.

In accordance with MTWS requirements, the force layout in the OBS was altered in two ways. First, the owning federate for all units, platforms, and lifeforms was changed to MTWS. Second, to set the aggregation level all subordinate units' instance data was made both not commandable and not simulated. If either commandable or simulated is checked when using an OBS XML, MTWS will aggregate the lower units as individuals vice the desired aggregation hierarchy, Figure 17.

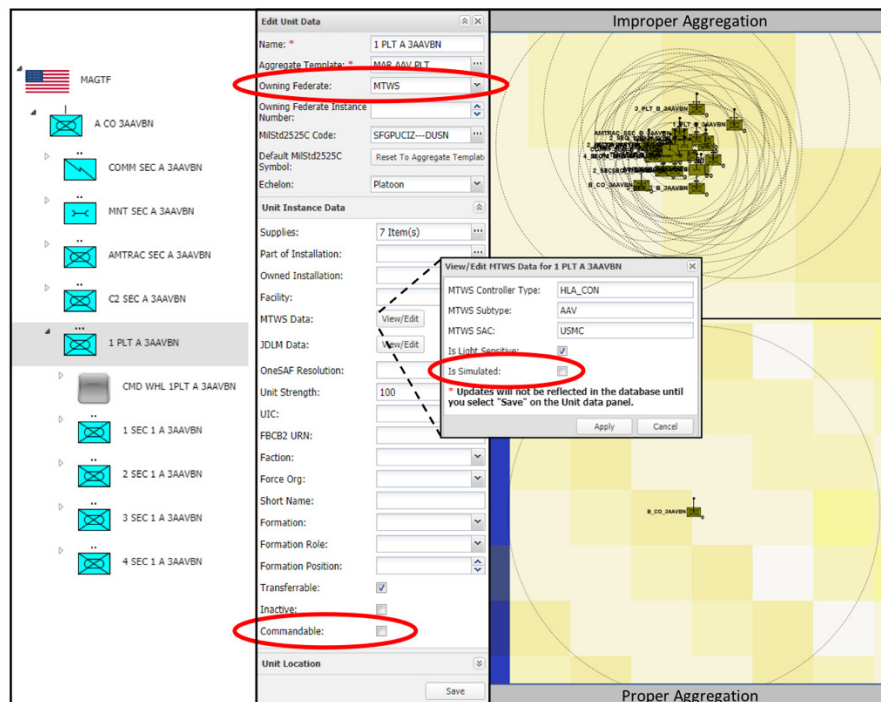


Figure 17. OBS alterations specific to MTWS

To create the synthetic environment MTWS contains a parametric database which houses extensive and detailed information concerning all possible occurrences of objects, events, interactions, and behaviors. The database is a cornerstone of the simulation, and to develop a scenario it is required that the STARTEX data match the parametric data (CESI,

2018). To check the compatibility of an OBS XML the OBS tool in the MDS is used, Figure 18. If errors are identified the parametric data is altered to match the OBS XML. For this analysis the baseline parametric data organic to the install of the system was used and required only one change to adjust the specific names of the sides, MAGTF and OPFOR.

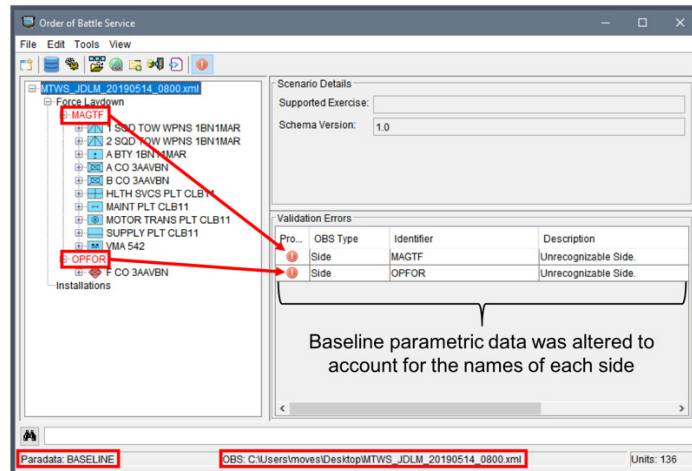


Figure 18. Parametric data and OBS force layout XML compatibility check

The OBS XML was converted into a MTWS force layout XML through the OBS tool on the MDS and loaded using the Command Entry tool, Figure 19.

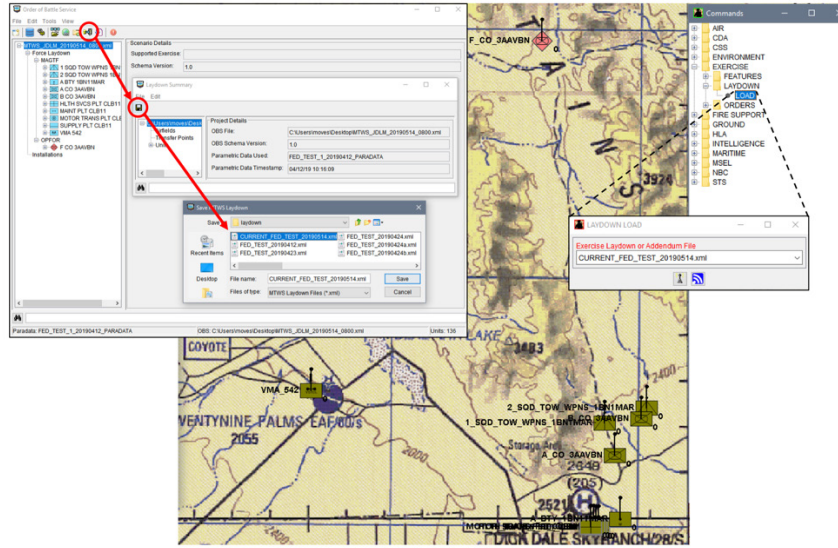


Figure 19. MTWS force layout XML conversion and load

The scenario was played out by initializing the force layout and running the simulation in the MSC. The units were maneuvered according to the tactical scenario script, outlined in Chapter III, through commands given by the user through the Command Entry tool on the MDS workstation, Figure 20. As a combat model, MTWS conducts automatic engagement between hostile forces when the forces detect each other. The movement of the units and the engagement resulted in the production of logistics data.

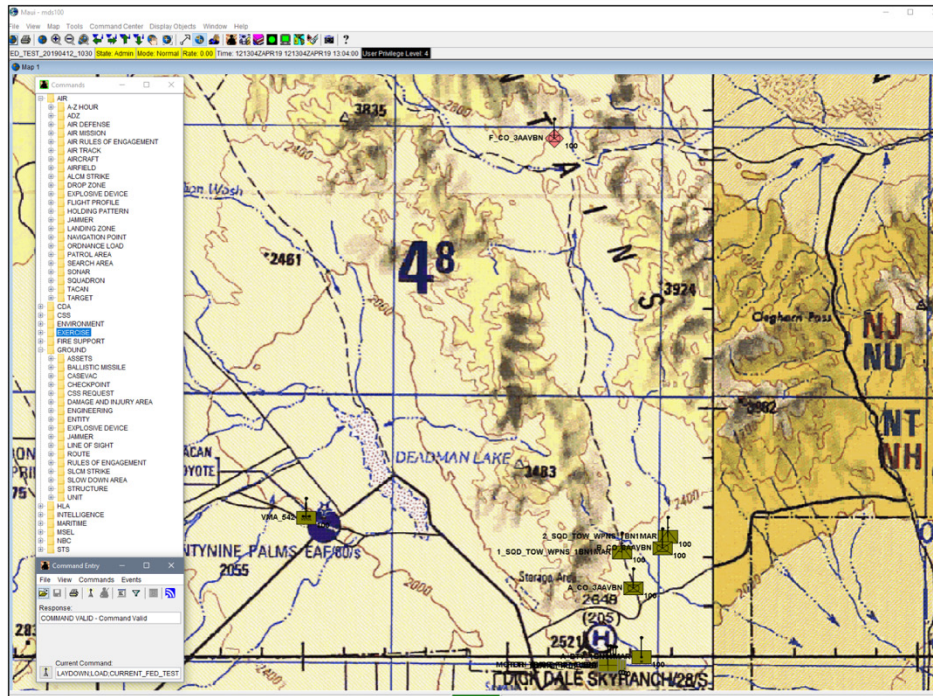


Figure 20. MTWS MDS workstation user interface

4. Logistics Capability

Logistics data in MTWS is collected through the personnel and asset reports for each unit. Reports for each unit were gathered before and after the scenario was played out for analysis, Figure 21.

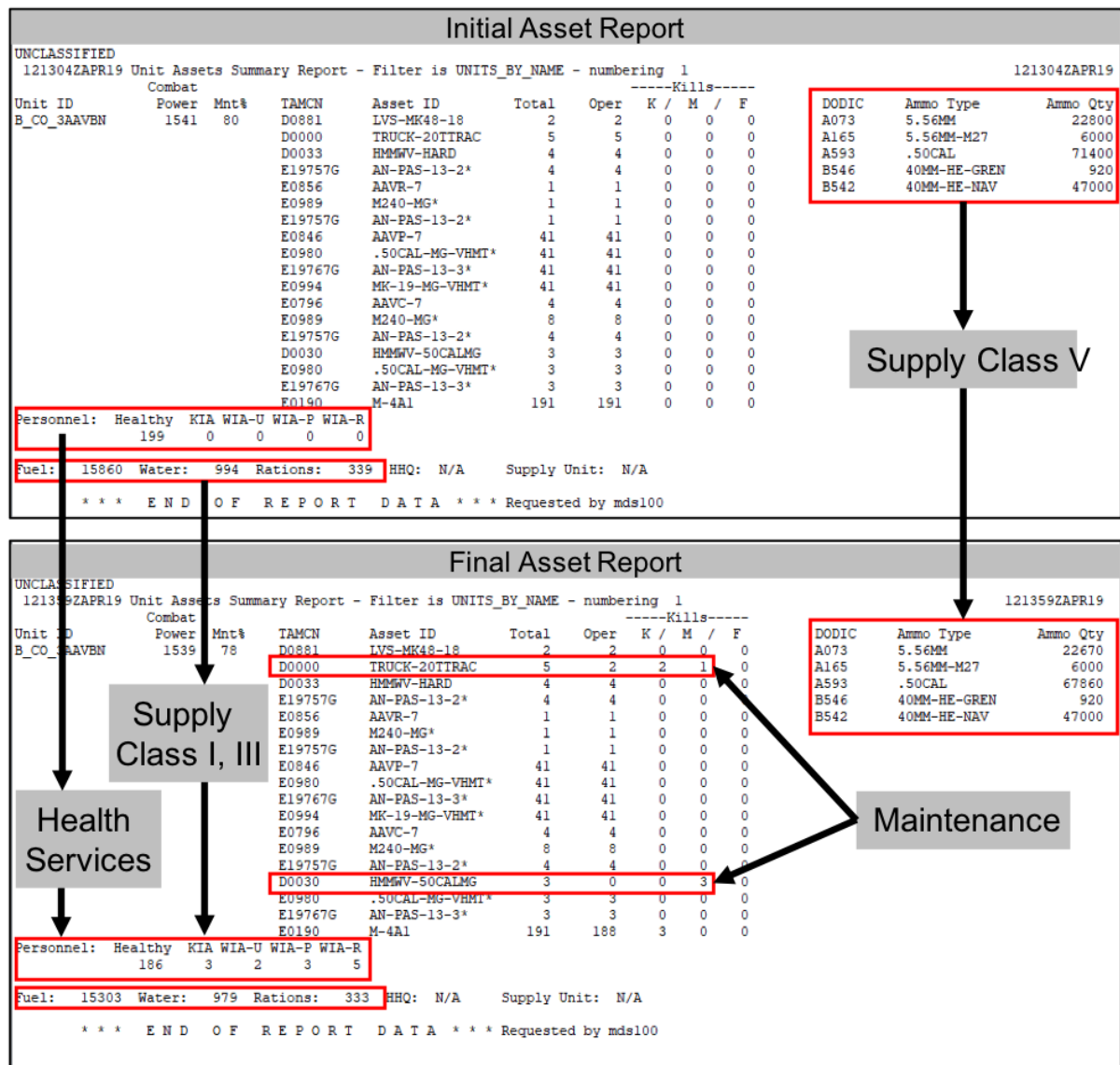


Figure 21. MTWS logistics data from the asset and personnel solicited reports

a. MTWS Supply Capability

MTWS captured classes I, III, V, and VII during the analysis. The data was quantitative in nature and consumption was demonstrated over time and through the engagement for all units in the scenario. Unit behavior is affected by decreasing supply levels in MTWS, without water, rations, or ammunition units have a combat power of zero. Likewise, units without fuel are unable to move in the simulation.

- Class I: Water and ration quantities are captured numerically and consumed over time and engagement, Figure 21.
- Class III: Fuel quantity is captured numerically and consumed during movement, Figure 21.
- Class V: Munitions are identified by DoD identification code (DODIC) and name. Quantities are displayed numerically and consumed during engagements, Figure 21.
- Class VII: MTWS documents the unit table of equipment in the asset report by TAMCN, name, and quantity, Figure 21.

b. MTWS Maintenance Capability

MTWS contains three categories for damage of equipment: catastrophic kill, mobility kill, and firepower kill. During engagement, when equipment is reported damaged, it is listed in the asset report under one of the categories, Figure 21.

- Catastrophic kill: Equipment is damaged beyond repair (CESI, 2018).
- Mobility kill: Equipment is no longer mobile and requires a tow and repair (CESI, 2018).
- Firepower kill: Equipment weapon systems are damaged and require repair (CESI, 2018).

c. MTWS Health Services Capability

Health services requirements are documented in both the asset report, Figure 21, and the personnel report for each unit, Figure 22. The details of the casualty are listed in the personnel report by generic name and rank. During engagements personnel casualties are classified into one of four categories:

- Killed in Action (KIA)
- Wounded in Action (WIA) Urgent

- WIA Priority
- WIA Routine

WIA casualties are evacuated through executing a casualty evacuation order, and treated through the combat support services orders in the command entry tool on the MDS workstation.

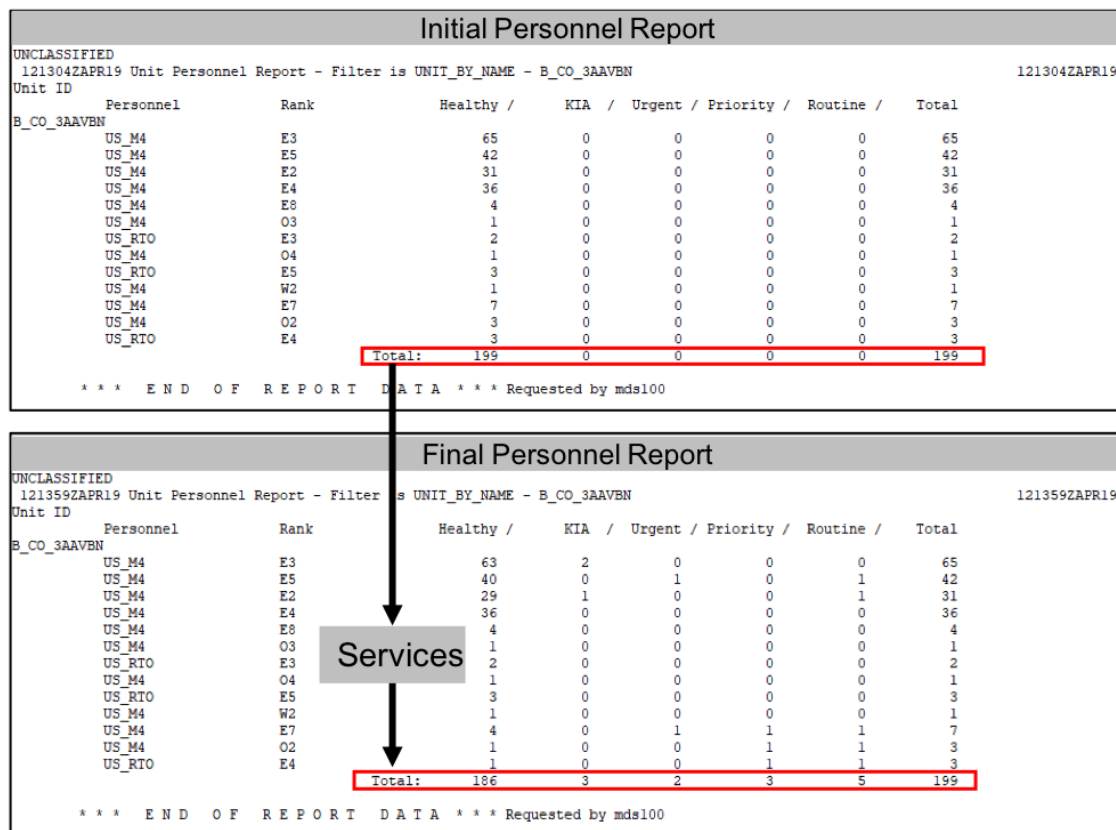


Figure 22. MTWS personnel report

d. MTWS Services Capability

MTWS handles personnel in a generalized manner. The personnel report covers the type of lifeform and how many of a specific rank exist in the unit. When casualties occur, it is quantified but not specific in the report, Figure 22.

5. Summary of Findings

MTWS is the current system used at MCLOG for training and is the control group for this research. The supply levels represented in the scenario include class I, III, and V consumed over time, and class VII assigned within unit table of equipment. The maintenance capability includes three classification of quantitative data assigned by TAMCN. The health service capability includes four classifications of casualty assigned quantitatively by personnel type and rank. The services capability includes only the limited ability to conduct numerical personnel administration. The logistics data collected during analysis support Conard's (2018) conclusion that MTWS has limited fidelity of logistics data and is only representing generalized information that requires alteration to increase fidelity for logistics C2 use, detailed in Chapter II.

B. JCATS ANALYSIS

1. Background

JCATS is a combat model at the entity level (MAGTF Training Directorate [MTD], 2019). Developed by the Lawrence Livermore National Laboratory (LLNL), "JCATS is a discrete event, constructive simulation that simulates actions and events of people and systems in specified environments" (LLNL, 2019, para 1). As a member of the JLVC federation, JCATS is sponsored by the J7 and is currently utilized as the primary entity ground simulation during joint exercises (LLNL, 2018). While the system is entity based, users have the capability to wrap units into higher echelons providing extensive flexibility to train a variety of audiences. JCATS is widely used across the DoD and internationally including 30 allied nations (LLNL, 2018). The system provides wargaming as a "man-on-man simulation" (LLNL, 2018, p. 2) allowing for a friendly and enemy force that can be played out and reviewed through after-action features.

The Marine Corps maintains minimal use of JCATS. However, it is utilized as a ground simulation for low level unit training through the MAGTF Training Command and formally used by the Marine Corps Tactics and Operations Group during training exercises for GCE operations officers (MTD, 2019). While the Army is transitioning to the Joint Land Component Constructive Training Capability, JCATS remains widely used for both

unit training and formal training exercise. JCATS is updated and maintained by LLNL in accordance with J7 requirement, and new versions are distributed to users via the JTDS.

2. Simulation Configuration

JCATS is designed to function as distributed clients sending and receiving data from a single server, referred to as the JCATS Data Server, Figure 23 (LLNL, 2017d). Both servers and clients are installed on computers or laptops, and do not require specific server hardware (LLNL, 2017d). While configurations vary depending on need, JCATS contains the functionality to support two types of data servers, and three types of clients, listed below.

- JCATS Data Server: This “workstation provides system wide services to all the client workstations and is generally used to run the simulation executable” (LLNL, 2017d, p.1-6). The server has the capability to act as a standard client allowing a single computer to act as both server and client (LLNL, 2017d).
- JCATS Web Server: The web server contains the same functionality as the data server, however, it allows for distribution to web clients running either RHEL or Window systems. (LLNL, 2017d)
- JCATS Standard Client: Standard client workstations provide an interface for the user to control entities within the simulation.
- JCATS Web Client: The web client contains the same functionality as the standard client, however, the JCATS configuration is not required for Linux or Windows OSs for the client to connect to the web server. (LLNL, 2017d)
- JCATS Bridges: Standard clients are designated as a bridge client to provide interoperability with other systems. JCATS provides the capability to facilitate HLA, distributed interactive simulation (DIS), and GCCS-TCO bridges (LLNL, 2017d).

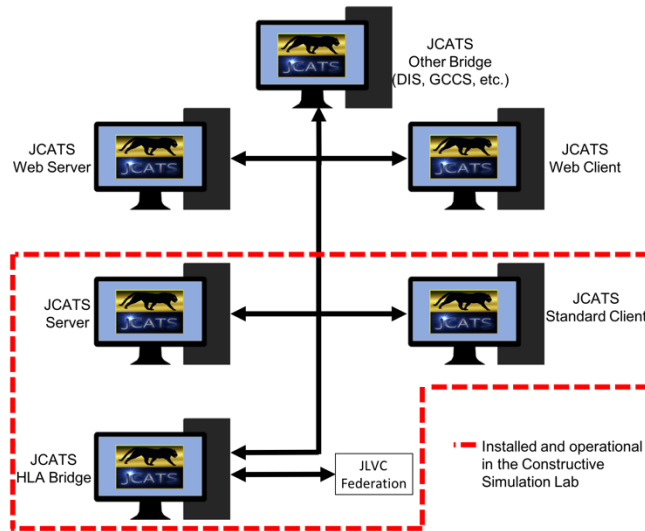


Figure 23. JCATS hardware diagram

The JCATS server starts an exercise and registers all client stations. The client workstations connect to the server workstation allowing the users to provide input and receive output from the server as the scenario is executed. Client stations acting as bridge clients receive data from the server and pass the information to the network. When joined in a federation, the client station acting as the HLA bridge is the single point of contact to the RTI. The DIS and GCCS-TCO bridges provide interoperability with C2 systems.

The constructive simulation lab contains a single computer running RHEL 6.9 in support of JCATS V 13.1. This computer operated as the JCATS server, a standard client workstation, and an HLA bridge workstation during the analysis, Figure 23. As this is not the recommended configuration when using JCATS, subject matter experts from LLNL were both consulted and provided in-person assistance for both the installation and scenario testing.

3. Tactical Scenario Implementation

The force layout was implemented into JCATS as STARTEX data using a five-step process, detailed below.

1. Change federate ownership to JCATS for all units, platforms, and lifeforms.

2. Match the OBS XML to the JCATS forces characteristics data file.
3. Convert the OBS XML to a JCATS force planning file.
4. Save the JCATS scenario setup file with new force plan.
5. Load the scenario setup file and run the exercise.

The only change made to the OBS scenario was the owning federate for each unit, platform, and lifeform. To quickly conduct a mass edit with an OBS scenario, the mass editor tool was used to change every child associated with each unit, Figure 24.

Figure 24. OBS mass editor tool to change owning federate

A JCATS scenario is built through three editing tools: the terrain editor, VISTA editor, and symbol editor (LLNL 2017c). The terrain editor houses data concerning the physical environment to include buildings, terrain features, roadways, and other infrastructure (LLNL 2017c). The data containing graphics for each entity in the simulation are contained in the symbol editor (LLNL 2017c). The VISTA editor controls “capabilities and parameters of the specific game to be played” (LLNL, 2017c, p. 2-2). All files concerning the scenario are contained in the VISTA editor including the data from the

symbol and terrain editor, Figure 25. These files combine to form the scenario file executed in the JCATS server.

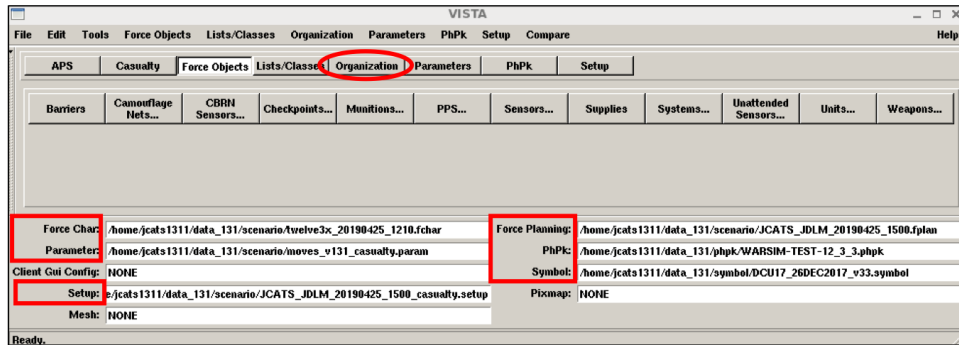


Figure 25. VISTA editor

To create a scenario file only six files of the VISTA editor are required: force characteristic, parameter, setup, force planning, probability of hit probability of kill (PhPk), and symbol.

- Force Characteristic: The force characteristic file contains the capabilities and attributes of every entity recognized by the system (LLNL, 2017c). Entities are identified by both name and DIS enumeration code. The force characteristic file used for this analysis was acquired from the J7.
- Parameter: The parameter “files control environmental, human factors and many other general aspects of a simulation” (LLNL, 2017c, 3–1). The parameter files used for this analysis were acquired from the J7.
- Setup: The setup file contains administrative information concerning the configuration of the scenario, and how forces are distributed to the workstations (LLNL,2017c). This file is created when the VISTA editor is saved to build the scenario file.

- Force Planning: The force planning file contains the organization of forces in the scenario including the task organization and table of equipment of each side and combat relationships (LLNL, 2017c).
- PhPk: The PhPk file “defines the effectiveness of each weapon against a specific target” (LLNL, 2017c, p. 3-1) considering range. The data provides the adjudication for direct fire engagement (LLNL, 2017c). The PhPk file used for this analysis was acquired from the J7.
- Symbol: The symbol file is acquired from the symbol editor. Symbology for this scenario was acquired from the J7.

To use an OBS XML as the STARTEX data for a JCATS scenario, the OBS XML was imported through the VISTA editor force organizational tool, to create the force planning file. Once the data was imported a compatibility check was conducted through the force organizational tool to ensure the entities in OBS XML were recognized by the force characteristic file, Figure 26.

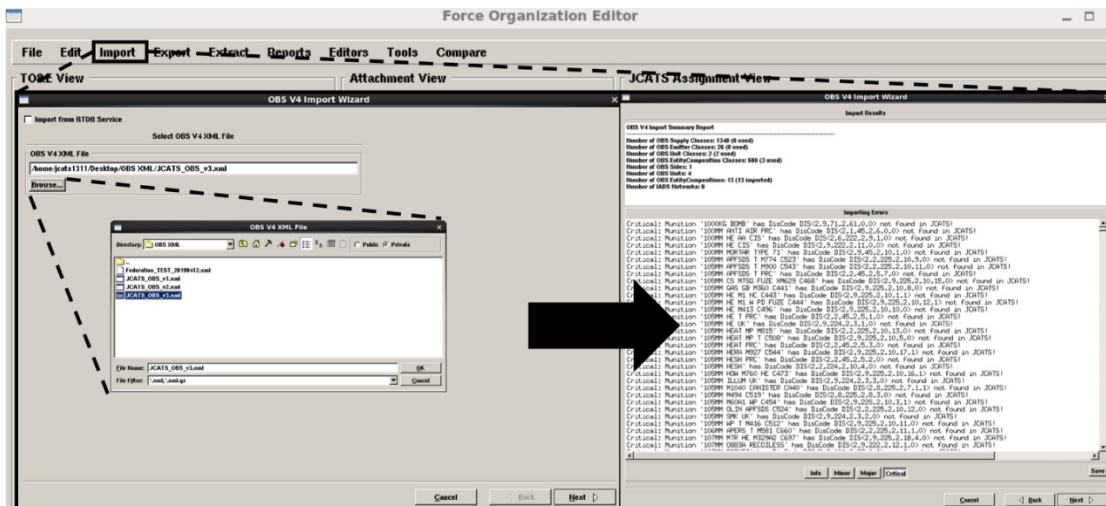


Figure 26. Force characteristic file and OBS force layout XML compatibility check

Unlike MTWS, differences in the OBS XML and force characteristic file do not prevent the user from running the scenario in JCATS. The errors identified in Figure 26 did not impact the scenario used for analysis and were ignored when creating the force planning file. Following the development of the force planning file, the scenario was saved and loaded into JCATS, Figure 27.

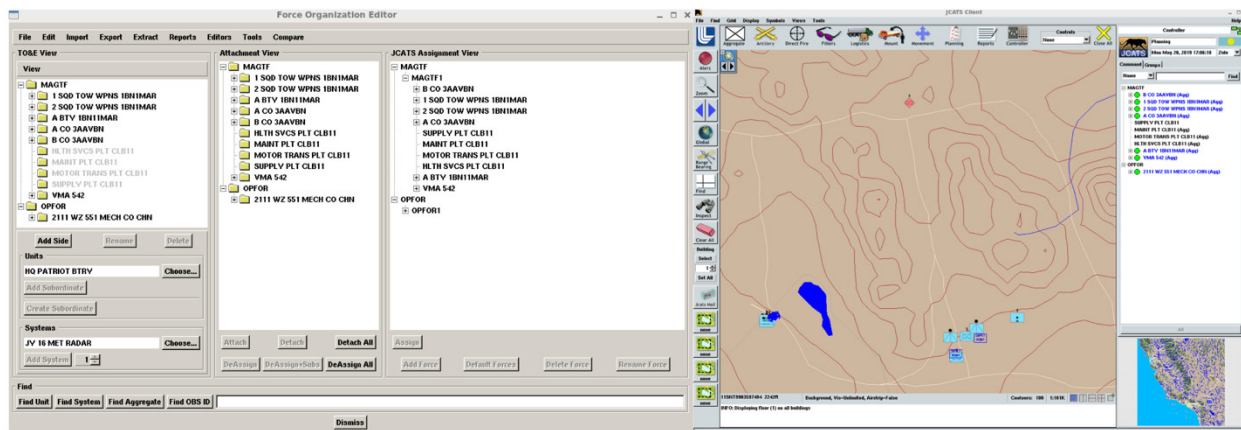


Figure 27. Final JCATS force planning file and scenario loaded into JCATS

To play out the scripted scenario, described in Chapter III, units were given orders through the client workstation. Entities are collected into a unit for the user to control using the tools within the interface, Figure 28. JCATS, as a combat model, initiates an engagement when hostile units are within range of each other. Logistics data is a result of engagements and operational maneuver. JCATS contains a casualty play feature which is turned on to produce higher fidelity logistics data and allow JCATS to fix damaged equipment and treat wounded personnel. For the individual JCATS analysis, casualty play was enabled.

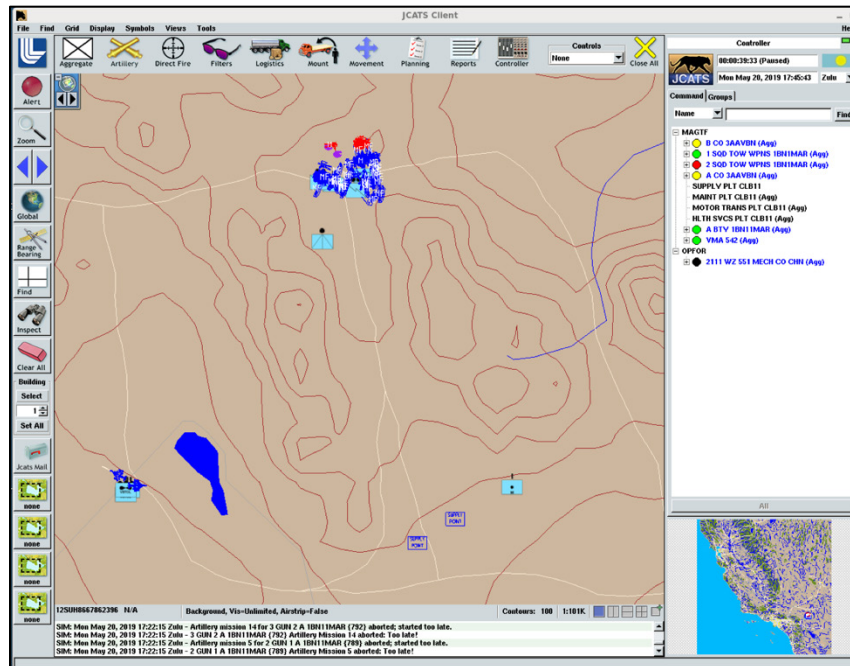


Figure 28. JCATS server workstation user interface

4. Logistics Capability

Logistics data in JCATS is contained in four reports: the entity carry report, entity ammo report, entity casualty report, and unit personnel report. Reports in JCATS are organized as comma separated files and displayed as a spreadsheet for the user. For the analysis, reports were pulled for each unit before and after the scenario was played out.

a. JCATS Supply Capability

Two categories of supply are represented in JCATS: carried supplies and personal supplies. Carried supplies consist of items contained within a unit meant specifically for resupply (LLNL, 2017a). Personal supplies consist of the supplies carried by the individual entity and consumed over time and operation (LLNL, 2017a). The force layout used in the tactical scenario established the only carried supplies at the unit level for the analysis. JCATS has the capability to represent classes I, III, IV, V, VII, VIII, and IX, however, class IX was not used in the scenario (LLNL, 2017a). The ammo report publishes the personal class V load of each entity within a unit (LLNL, 2017b).

Carrier Name # Alive	Supplies	Fuel Gals	%	Weight Lbs	%	Volume m^3	%
SUPPLY POIN	1 369528 lbs (6%)	500000		91 3619528	61	8249	1
	AFV NET: 100 of 100 each (10000 of 10000 lbs)			10000	0.2	200	0
	AMINOPHYLLINE INJ 255: 500 of 500 each (1 of 1 lbs)			0.5	0	0.5	0
	ATROPINE SULF INJ105: 1200 of 1200 each (1 of 1 lbs)			1.2	0	1.2	0
	BAND CTN 5YDX6: 10000 of 10000 each (100 of 100 lbs)			100	0	100	0
	BLOOD RECIPIENT 485: 600 of 600 each (300 of 300 lbs)			300	0	6	0
	CATHETER URE 16FR 125: 300 of 300 each (3 of 3 lbs)			3	0	3	0
	CATHETER URETHRAL 16FR: 300 of 300 each (3 of 3 lbs)			3	0	3	0
	CATHETER AND CON TRACS505: 300 of 300 each (3 of 3 lbs)			3	0	3	0
	DIAZEPAM INJ 2ML 105: 100 of 100 each (0 of 0 lbs)			0.1	0	1	0
	DRESSING BURN24K36: 1000 of 1000 each (1 of 1 lbs)			1	0	10	0
	DRESSING FIRST AID: 10000 of 10000 each (10 of 10 lbs)			10	0	10	0
	Food: 36000 of 36000 ration (9000 of 9000 lbs)			9000	0.2	3600	0.4
	GENTAMICIN SUL 50ML24: 1000 of 1000 each (1 of 1 lbs)			1	0	1	0
	INTRAVENOUS INJ 5E485: 1000 of 1000 each (1 of 1 lbs)			1	0	1	0
	MASK ORONASAL ADLT50565151150032: 500 of 500 each (1 of 1 lbs)			0.5	0	0.5	0
	MORPHINE 10MG 1ML 105: 2500 of 2500 each (3 of 3 lbs)			2.5	0	2.5	0
	NEEDLE HYPO 22GA 1005: 2500 of 2500 each (3 of 3 lbs)			2.5	0	2.5	0
	PAD BED LINEN PROT300: 500 of 500 each (50 of 50 lbs)			50	0	5	0
	PENICILLIN G 1005: 2500 of 2500 each (3 of 3 lbs)			2.5	0	2.5	0
	RINGER INJ 500ML 185: 2500 of 2500 each (3 of 3 lbs)			2.5	0	2.5	0
	SUTURE ABS SZ 1-0 365: 10000 of 10000 each (10 of 10 lbs)			10	0	10	0
	SYRINGE HYPO 10ML1005: 1000 of 1000 each (1 of 1 lbs)			1	0	1	0
	Sandbag: 5000 of 5000 each (125000 of 125000 lbs)			125000	2.1	500	0
	TUBE DRAIN 32FR 105: 1000 of 1000 each (10 of 10 lbs)			10	0	10	0
	TUBE TRACH 8MM ID 105: 1000 of 1000 each (10 of 10 lbs)			10	0	10	0
	VANCOMYCIN HCL 500MG: 1000 of 1000 each (1 of 1 lbs)			1	0	1	0
	WATER STER 1000ML 125: 1000 of 1000 each (10 of 10 lbs)			10	0	10	0
	AIRWAY PHARYN SM ADL: 1800.00 of 1800 6 (2 of 2 lbs)			1.8	0	1.8	0
	Water: 25000.00 of 25000 gallons (162500 of 162500 lbs)			162500	2.7	2500	0.2
	Wire: 2500.00 of 2500 rolls (62500 of 62500 lbs)			62500	1.1	1250	0.1

Figure 29. JCATS carry report

- Class I: Water and ration quantities are captured numerically, by quantity weight and volume, Figure 29.
- Class III: Fuel quantity is captured numerically, by weight and by volume, Figure 29.
- Class IV: Construction materiel is listed by quantity, by weight, and by volume, Figure 29.
- Class V: The quantity and type of ammunition is contained in the ammo report by entity. Class V is consumed through engagement and identified by name and DODIC, Figure 30.
- Class VII: Major end items are captured by name and are considered entities in JCATS, Figure 30.
- Class VIII: Medical supplies are contained in the carried supplies, Figure 29.

Initial Ammo Report						
ID	Name	Station	Weapon	Munition	Rounds Left	% Left
471	1 1 1 TRK A 3AAVBN		1 12.7MM MG M2	50CAL A534	900	100
			40MM AGL MK19	40MM HEDP M430 B542	375	100
479	2 2 1 TRK A 3AAVBN		1 12.7MM MG M2	50CAL A534	900	100
			40MM AGL MK19	40MM HEDP M430 B542	375	100
483	1 2 1 TRK A 3AAVBN		1 12.7MM MG M2	50CAL A534	900	100
			40MM AGL MK19	40MM HEDP M430 B542	375	100
Final Ammo Report						
ID	Name	Station	Weapon	Munition	Rounds Left	% Left
471	1 1 1 TRK A 3AAVBN		1 12.7MM MG M2	50CAL A534	310	34.4
			40MM AGL MK19	40MM HEDP M430 B542	375	100
479	2 2 1 TRK A 3AAVBN		1 12.7MM MG M2	50CAL A534	320	35.6
			40MM AGL MK19	40MM HEDP M430 B542	375	100
483	1 2 1 TRK A 3AAVBN		1 12.7MM MG M2	50CAL A534	160	17.8
			40MM AGL MK19	40MM HEDP M430 B542	375	100

Figure 30. JCATS ammo report

b. *JCATS Maintenance Capability*

By enabling casualty play when the scenario was set up in the VISTA editor, fidelity of maintenance was increased. Vehicle damage is contained in the casualty report by entity. The report displays the item damaged and provides the type of damage, a description of the damage, and time of repair. JCATS classifies system status as mobility, firepower, or dead. Repairable entities can be repaired by a user through the logistics commands in the client workstation.

- Mobility: Entities classified as mobility damage cannot move but maintain the ability to employ attached weapon systems.
- Firepower: Entities classified as firepower damage are mobile, but do not have the ability to employ weapon systems.
- Dead: Entities classified dead, can neither move or employ weapon system. When an entity is classified as dead it cannot be repaired.

ID	Name	Class	System Status	SubSystem	Casualty Code	Description	Level	Repair Time
620	MESS A 3AAVBN	MTV CARGO M1083	MobFr	Mobility & Firepower	117	MTV CAB ASSY	N/A	5 hours
637	2 LVS A 3AAVBN	PLS M1075	Dead	Firepower	Not Fixable			
				Mobility	Not Fixable			
400	1 MNT A 3AAVBN	MTV CARGO M1083	Mob	Mobility	113	MTV FRONT AXEL	N/A	2 hours
				Mobility	112	MTV RADIATOR	N/A	3 hours

Figure 31. JCATS maintenance casualty report

c. JCATS Health Services Capability

Similar to the maintenance capability, enabling the casualty play increases the fidelity of medical data. JCATS classifies personnel casualties the same as maintenance casualties as mobility, firepower, or dead, Figure 32. However, when a lifeform status is classified as mobility it reflects as a WIA in the personnel reports. JCATS identifies specific casualties by entity general name and identification number, and assigns a specific injury coupled with treatment time, and time before death if untreated. If the lifeform is left untreated for the specified time the status will change to dead in the casualty report and KIA in the personnel report. While not used in this scenario, JCATS has the ability to assign gender and blood type to an entity. Users can repair lifeform casualties through the logistics commands in the client interface.

ID	Name	Class	Gender	Blood	Religious Affiliation	System Status	SubSystem	Casualty Code	Description	Level	Needed To Recover	Untreated Time of Death	Repair Time
1262	2 RIFLE 1 3 2111 WZ 551 MECH CHN	GL RFL 5.8MM TYPE 95				Mob	Mobility	215345	SHRAPNEL WOUND OF THE SPLEEN	0	Untrained	Day 0 00:56:33	15 minutes
1263	PSG 3 2111 WZ 551 MECH CHN	GL RPO				Dead	Firepower	Not Treatable					
							Mobility	Not Treatable					

Figure 32. JCATS health services casualty report

d. JCATS Services Capability

The primary capability in JCATS for logistics services is personnel administration. Each lifeform entity is assigned a specific identification number and represented using billet description, grade, and military occupational specialty (MOS). While KIAs are recorded and can be replaced, mortuary affairs is not represented in JCATS. The JCATS

personnel report displays the lifeform entities in each unit and the overall percentage of the unit.

2 SQD TOW WPNS 1BN1MAR								
Billet	Grade	MOS	Total Auth	Current	WIA	KIA	Percent	
DRIVER TOW 3 WPNS 1BN1MAR	E3	0352	1	1	0	0	100%	
DRIVER TOW 4 WPNS 1BN1MAR	E3	0352	1	1	0	0	100%	
GUNNER TOW 3 WPNS 1BN1MAR	E4	0352	1	1	0	0	100%	
GUNNER TOW 4 WPNS 1BN1MAR	E4	0352	1	1	0	0	100%	
LDR 2 TOW WPNS 1BN1MAR	E5	0352	1	1	0	0	100%	
<Total>			5	5	0	0	100%	

Figure 33. JCATS personnel report

5. Summary of Findings

While JCATS logistics capability is more advanced than MTWS, the implementation of JCATS into the MCLOG infrastructure requires a complete overhaul of the existing layout both in hardware and software. Furthermore, the requirement for the training support staff to switch from MTWS to JCATS and gain proficiency would take time slowing the existing training cycle. The secondary concern with switching from MTWS to JCATS is starting from a baseline data source. Starting from baseline data, it is likely that the VISTA editor files require some level of adjustment to suit the needs of MCLOG and prevent unrealistic behavior from the model. Identifying problematic behavior requires time and exercise repetition.

The fidelity of logistics data in JCATS is increased compared MTWS. The classes of supply were increased to include classes IV, VIII, and IX. The maintenance information was increased to a specific casualty code and required repair time, however TAMCN were not included in JCATS. While health services casualties did not include classification as routine, priority, or urgent, the fidelity of data increased to include specific injury, blood type, gender, and religion of the casualty, treatment time, and time before death if untreated. Services information was also increased to include MOS, gender, and religion.

The capability for simultaneous training is similar to MTWS with no advantage between the two simulations established. As both simulations are combat models, they are both designed to support GCE and ACE operations differing only in LCE support.

JCATS presents increase in fidelity of logistics data, but at the cost of time to retrain the staff, outfit the hardware, and adjust new databases to MCLOG needs. The increase of training capability does not validate the time and cost requirements to adjust the infrastructure for implementation.

C. JDLM ANALYSIS

1. Background

The JDLM is a logistics entity-based constructive simulation designed by Tapestry Solutions, a Boeing Company, “that enables logistics personnel to exercise their C2 systems in a realistic combat environment” (Tapestry Solutions, 2019b, para 7). The system was originally funded by United States Army Europe to provide a logistics training tool for commanders and their staffs “when conducting mission planning, rehearsals, and training associated with power projection” (Swan, 2006, para 2). The system caters to all levels of command and is specifically designed to provide detailed logistics capability in transport, supply consumption and operations, medical services, medical supply consumption, maintenance, and personnel treatment and replacement (Tapestry Solutions, 2016). As a member of the JLVF federation, JDLM is used as the primary logistics model during J7 exercises and contains gateways to HLA, DIS, and GCCS-TCO.

There is limited use of JDLM in the Marine Corps, however it is used extensively in the Army and for joint exercises. Currently, I MEF simulation center is working to advance the use of JDLM in the Marine Corps, along with the increased use and interest at both MCLOG and MSTP. JDLM is maintained and updated by Tapestry Solutions and distributed through the JTDS to users.

2. Simulation Configuration

JDLM is a server client system designed for distributed operation. The same software is used for both the server and client workstations. The JDLM configuration, Figure 34, consist of a combination of a server, clients, client gateways, and, when federating, the JDLM HLA listener (Tapestry Solutions, 2016).

- Server: The server acts as the data base for the scenario, both maintaining and saving the data. The computer used as the server acts as a client, registers all the clients in the exercise, and runs the gateway to the JLVC federation (Tapestry Solutions, 2016).
- Client: The client connects to the server through IP address and receives the common database from the server allowing distributed operations. Up to ten clients can connect to the server prior to the system becoming degraded (Tapestry Solutions, 2016).
- Client Gateway: The client gateway increases distribution capability beyond ten clients by connecting to the server and allowing clients to connect to it, Figure 34 (Tapestry Solutions, 2016).
- HLA Listener: The HLA listener is a separate piece of software that runs on a RHEL OS. JDLM does not connect directly to the JLVC federation and requires an intermediary software which connects to the RTI. The JDLM server broadcast all data to the HLA listener and receives information from federation through the HLA listener (Tapestry Solutions, 2016).

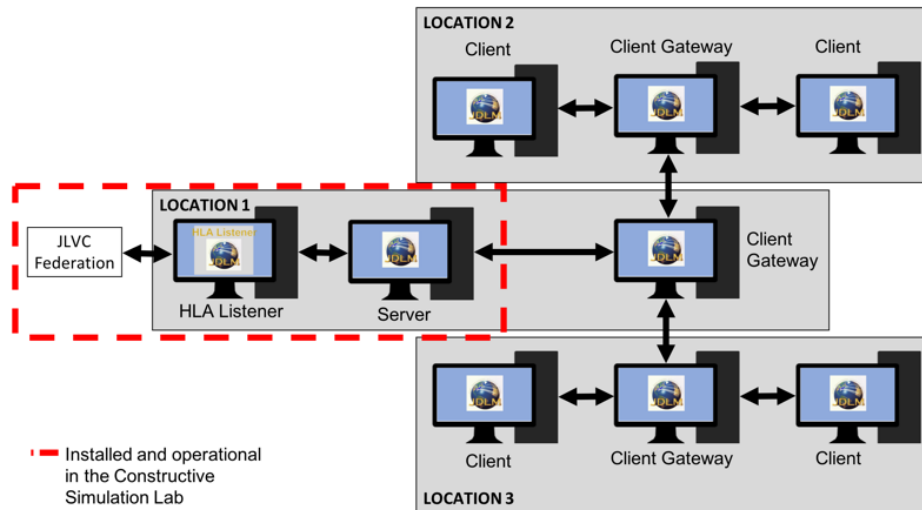


Figure 34. JDLM distributed hardware diagram

A JDLM project or database is created using the server workstation. The server controls the configuration of the project by registering clients and the JLVC gateway, if necessary. The clients join the project through IP address and establish any required gateways for that specific computer such as a the GCCS gateway for C2 systems. Clients send and receive information to and from server during the exercise, and the project data is saved on the server for future use.

In the constructive simulation lab, JDLM version r30.07.03 was installed on a single computer running Windows 10 OS, and the JDLM HLA listener was installed on a second computer running RHEL 6.8, Figure 34. During analysis, the JDLM workstation acted as both server and client.

3. Tactical Scenario Implementation

The force layout was implemented into JDLM as STARTEX data using a four-step process, detailed below.

1. Change federate ownership to JDLM for all units, platforms, and lifeforms.
2. Import the OBS XML and link with repository prototypes.

3. Establish consumption regions to replace combat.
4. Layout the scenario by moving units through consumption regions.

Similar to the JCATS requirements, the mass editor was used to apply JDLM as the owning federate for all entities. The OBS has the option of assigning JDLM capabilities to units, however, this function was not used for analysis. The logistics capabilities of units were assigned in JDLM after the OBS XML was imported.

JDLM scenarios are driven through databases, or repositories, that hold all the entities, or prototypes, in the scenario, and all the events, or conditions, that can occur to those entities. Prior to loading an OBS XML the user loads specific repositories to support the exercise, Figure 35. The repositories used in the scenario were acquired from the J7.

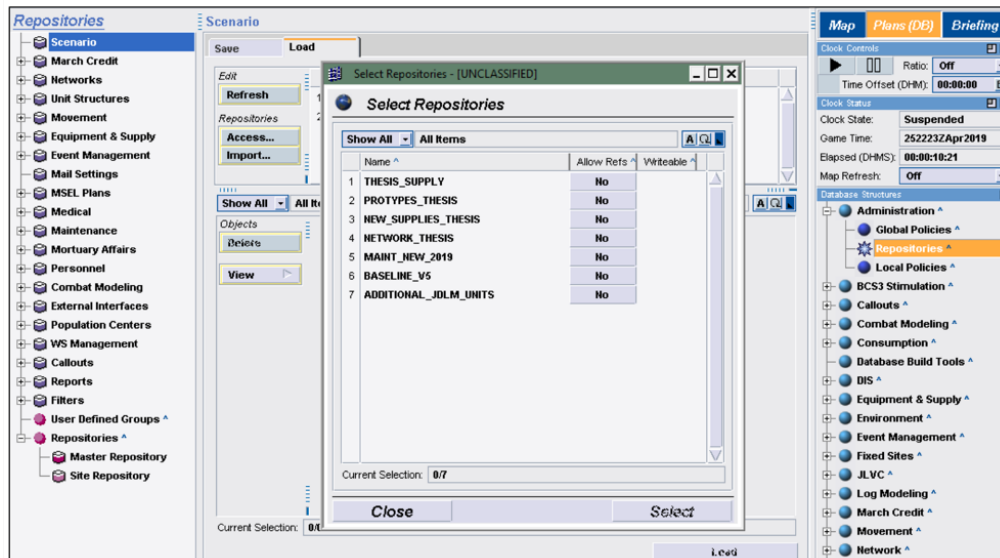


Figure 35. JDLM repositories

The OBS XML is loaded through the Import JLVC XML tool on the client workstation, and is automatically linked to the repository to check for compatibility of prototypes. Per JDLM requirements, all platform entities in the OBS XML file are required to be linked to prototypes in the repository, Figure 36. By linking the OBS XML platforms

to the repository prototypes, maintenance conditions are assigned when damage occurs in the exercise.

Desc ^	Kind (liberal)	Dom	Cnt	Cat	Sub	Spc	Ext	Symbol ^	Linked Item	Type ^	Sup	Int	Ign	Dis	Has	Last Entry ^
1 TIL WATER 400 GAL M	Platform	1	225	17	1	1	0		TIL WATER 400	MILU_LOAD_PROTO	No	Yes	Yes	No	No	
2 PLS M1975	Platform	1	225	7	38	0	0		PLS M1975	MILU_LOAD_PROTO	No	Yes	Yes	No	No	2 LVS A 3AA
3 MTV WRECKER M1989	Platform	1	225	7	12	17	3		MTV WRECKER	MILU_LOAD_PROTO	No	Yes	Yes	No	No	
4 MTV CARGO M1983 M	Platform	1	225	7	12	3	2		MTV CARGO M1	MILU_LOAD_PROTO	No	Yes	Yes	No	No	2 PM 1 A 1B
5 MTV CARGO M1983 M2	Platform	1	225	7	12	3	3		MTV CARGO M1	MILU_LOAD_PROTO	No	Yes	Yes	No	No	OPS CH WRL
6 MTV CARGO M1983 M2	Platform	1	225	7	12	3	1		MTV CARGO M1	MILU_LOAD_PROTO	No	Yes	Yes	No	No	3 PM 2 A 1B
7 MTV CARGO M1983	Platform	1	225	7	12	3	0		MTV CARGO M1	MILU_LOAD_PROTO	No	Yes	Yes	No	No	1 CGO AMMO
8 MK48 LVS CGO	Platform	1	225	7	18	1	0		MK48 LVS CGO	MILU_LOAD_PROTO	No	Yes	Yes	No	No	
9 M777 155MM TOWED H	Platform	1	225	5	6	0	0		M777 155MM TO	MILU_LOAD_PROTO	No	Yes	Yes	No	No	2 GUN 2 A 1
10 HMMVV CARGO M998	Platform	1	225	6	1	1	0		HMMVV CARGO	MILU_LOAD_PROTO	No	Yes	Yes	No	No	2 FBC A 10H
11 HMMVV ARMORED M1	Platform	1	225	6	1	21	5		HMMVV ARMO	MILU_LOAD_PROTO	No	Yes	Yes	No	No	TOW 4 WPLS
12 HMMVV ARMORED M1	Platform	1	225	6	1	21	3		HMMVV ARMO	MILU_LOAD_PROTO	No	Yes	Yes	No	No	30 WRL A 1B
13 HMMVV ARMAMENT C	Platform	1	225	6	1	3	2		HMMVV ARMA	MILU_LOAD_PROTO	No	Yes	Yes	No	No	15C WRL A 1
14 HMMVV ARMAMENT C	Platform	1	225	6	1	3	1		HMMVV ARMA	MILU_LOAD_PROTO	No	Yes	Yes	No	No	CBR WRL A 1
15 FORKLETT VPRITLY	Platform	1	225	7	27	0	0		FORKLETT VPRIT	MILU_LOAD_PROTO	No	Yes	Yes	No	No	FL AMMO A 1
16 AV8D HARRIER	Platform	2	225	2	0	1	0		AV8D HARRIER	MILU_LOAD_PROTO	No	No	Yes	No	No	HARRIER 10
17 AAV7A1	Platform	1	225	2	25	2	0		AAV7A1	MILU_LOAD_PROTO	No	Yes	Yes	No	No	RTVR A 3AAV
18 AAV7A1	Platform	1	225	2	25	6	0		AAV7A1	MILU_LOAD_PROTO	No	Yes	Yes	No	No	3 13 TRK A
19 AAVC7A1	Platform	1	225	2	25	1	0		AAVC7A1	MILU_LOAD_PROTO	No	Yes	Yes	No	No	4 C2 A 3AAV

Figure 36. JDLM linking prototypes with OBS XML platforms

Logistics data in JDLM cannot be generated through combat, as JDLM is a logistics model, therefore, to generate logistics data an alternative method is used. Consumption regions were used to replace combat and generate logistics requirements for this analysis, Figure 37. JDLM utilizes region agents to manually set rates of specific consumption events, such as fuel consumption, ammunition consumption, casualty rates, vehicle damage, etc. The agents are applied to geographical regions, which impact units within the area. This method replaces combat and is designed to stimulate logistics requirement over time. The units were maneuvered through these regions in accordance with the scripted tactical scenario to collect data for analysis.

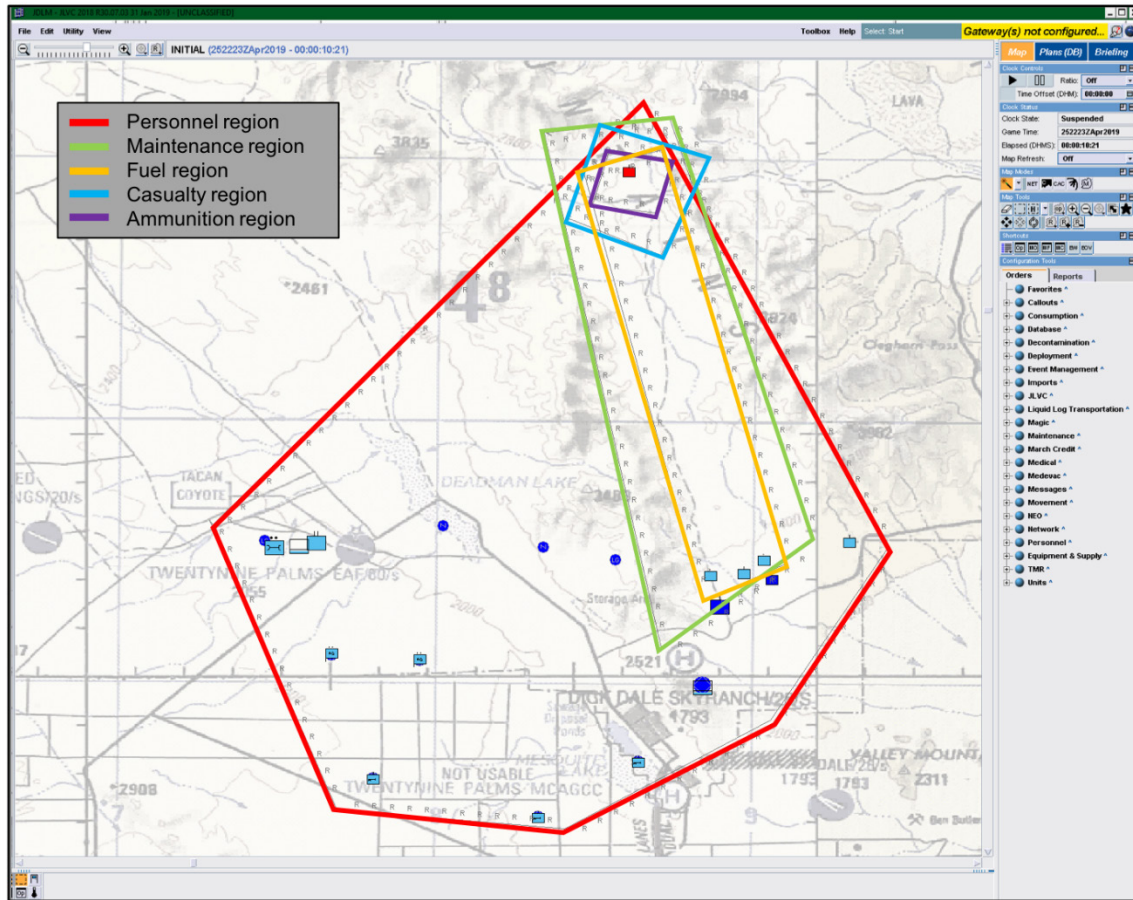


Figure 37. JDLM consumption regions

4. Logistics Capability

JDLM generates logistics data from specific consumption rates defined by the user, described above, or from conditions contained in the repositories. A condition in JDLM is the description of a consumption event including all low-level details of the event. As a logistics model, JDLM can represent all functions of logistics in detail. However, most of Marine Corps general engineering is considered combat oriented, and therefore not represented in the model, Table 3 (Conard, 2018). Of the four functions of logistics examined in the analysis, JDLM provides an extensive amount of information.

a. JDLM Supply Capability

JDLM has the capability of representing all classes of supply, blood, mail, and miscellaneous items, Figure 38. While class II, VI, and X are available in JDLM only class I, III, IV, V, VII, VIII, and IX were observed in the scenario.

- Class I: Water and rations were identified numerically by unit of measurement and storage volume. Specialized MREs, such as religious preference, are captured in the system. JDLM further differentiates rations to include unitized group rations and other bulk food supplies. Water is described in greater detail as well, accounting for ice, drinking by various volumes, and sterilized water for medical use. Class I consumption is stimulated by user input.
- Class III: Fuel quantity is captured numerically by unit of measurement and storage volume. Various oils, lubricants, and different fuel types are represented in the system through national item identification number (NIIN). Class III consumption is stimulated by user input and maintenance conditions.
- Class IV: Construction materials are identified by name, NIIN, quantity, and storage volume. The supplies include requirements for both vertical and horizontal construction. Consumption of class IV was not observed during this scenario.
- Class V: Ammunition is classified by name, DODIC, and dimension. Class V is consumed through user input and consumption region.
- Class VII: Major end items are captured by name, TAMCN, serial number and dimension. Maintenance conditions are established for each piece of equipment within the maintenance repository described below.
- Class VIII: Medical supplies are described by name, NIIN, quantity, and dimension. The supplies include both expendable items, blood product,

medications, and user defined miscellaneous items. Class VIII is consumed through treatment conditions and user input.

- Class IX: Repair parts are described by name, NIIN, quantity, and dimension. Class XI is consumed through maintenance conditions.

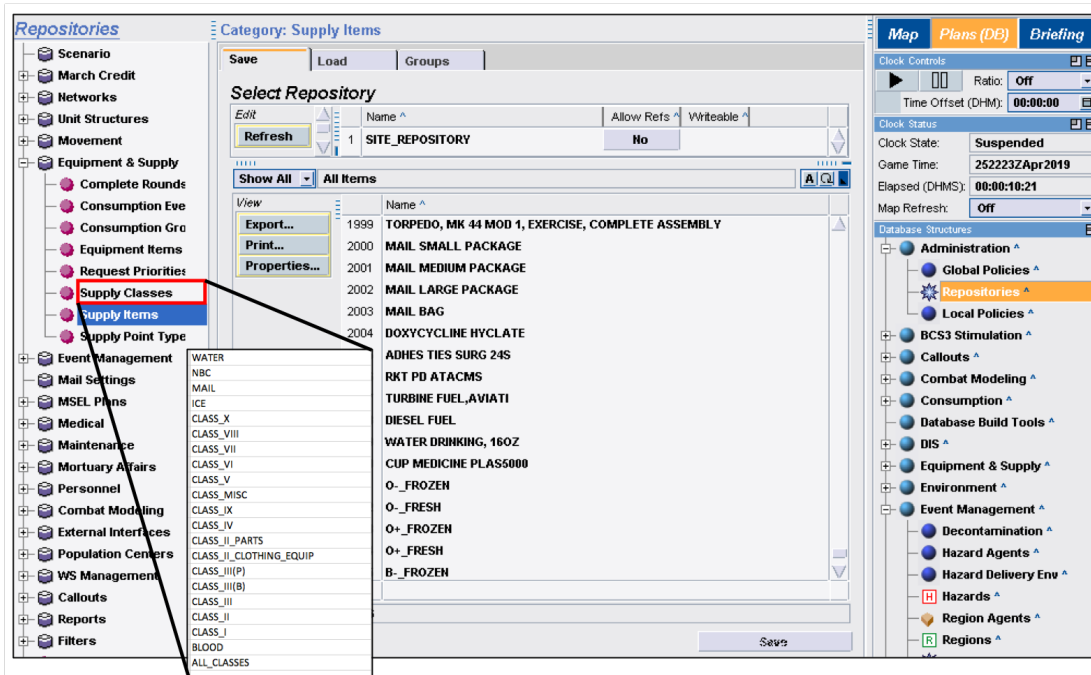


Figure 38. JDLM supply capability

b. JDLM Maintenance Capability

JDLM describes maintenance requirements in the form of maintenance conditions. These conditions are specific to individual pieces of equipment and contain the detailed requirements to repair the damage, Figure 39. When a piece of equipment is damaged in the system, a maintenance condition is selected at random and assigned to the entity. The condition includes the name of the repair, the time of repair, the assigned maintenance unit, and the specific supplies that will be expended during the repair. If the unit does not contain the supplies required to fix the maintenance condition the repair does not start. The maintenance condition also contains a chronological record of events associated with the

repair of the entity. For entities that are beyond repair, JDLM contains the ability to replace the equipment. Damage occurs to equipment by user input through a consumption event or region.

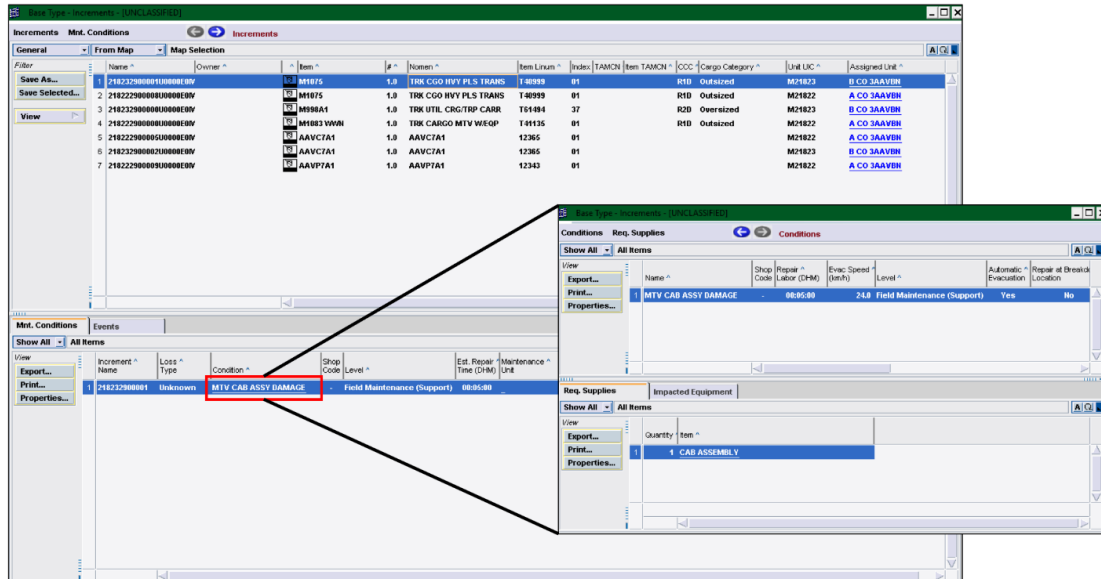


Figure 39. JDLM maintenance condition

All maintenance conditions are contained in the maintenance repository, Figure 40, acquired from the J7. This repository can be customized by the individual user to contain all maintenance conditions for equipment used in exercises.

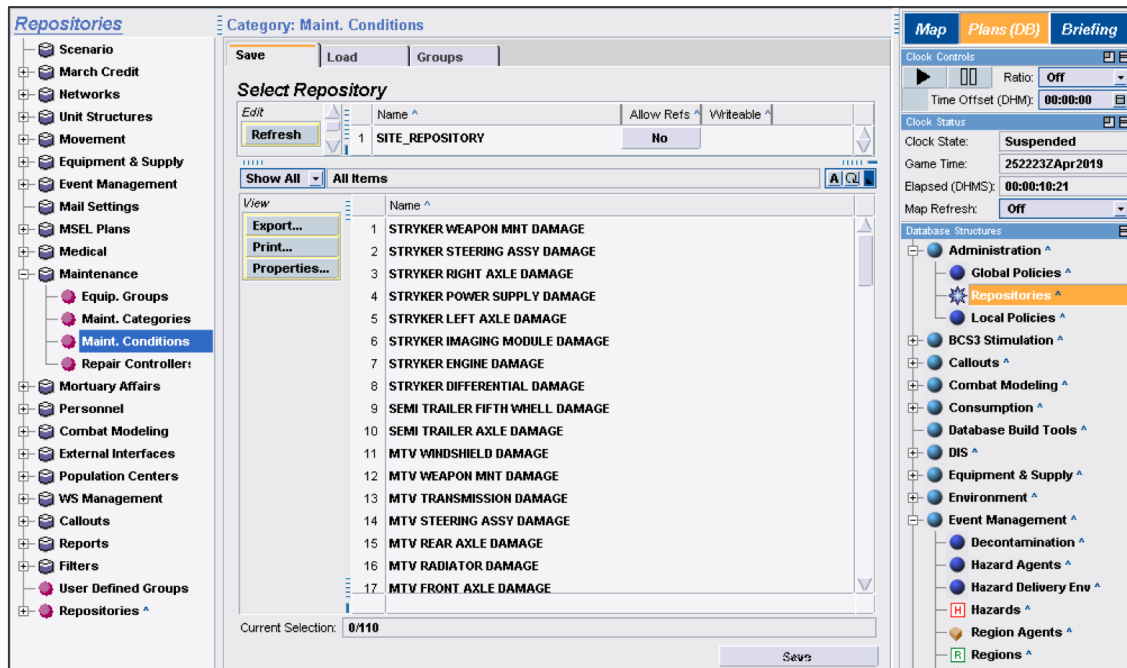


Figure 40. JDLM maintenance repository

c. JDLM Health Services Capability

JDLM provides health services capability in the same form as maintenance capability. The medical repository contains all injuries that can occur to a lifeform in the scenario referred to as treatment briefs, Figure 41. When a lifeform is registered as a casualty a treatment brief is randomly assigned to the entity. Similar to maintenance conditions, treatment briefs contain specifically what injury was sustained, which triage of care is required, estimated time before death if not treated, estimated time of treatment, and medical supplies required.

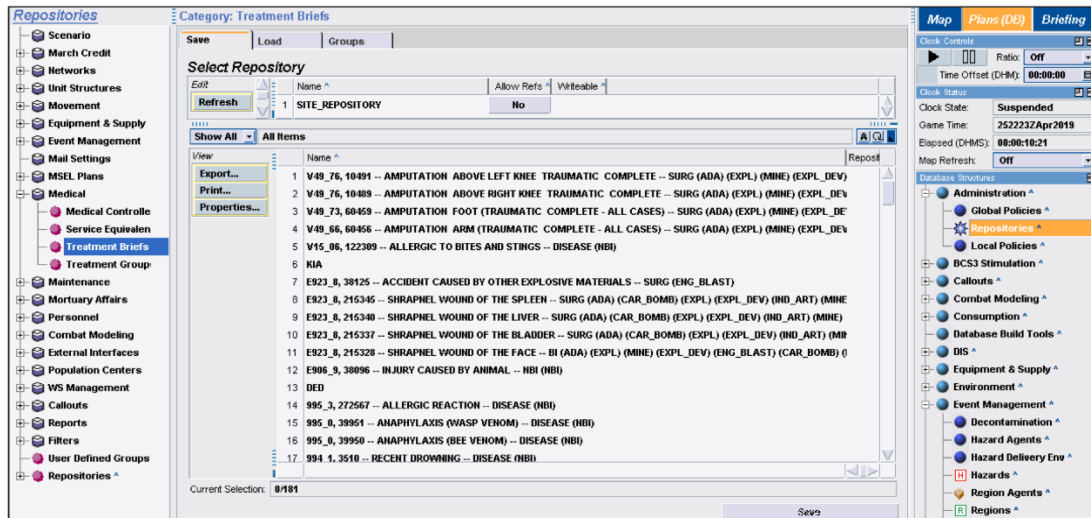


Figure 41. JDLM health services repository

Lifeforms in JDLM contain detailed information including a specific name, social security number, rank, MOS, blood type, gender, and religion. MOS is defined by the OBS XML, names, blood type, gender, and religion are generated through a JDLM repository, or are imported by the user to match a specific roster. Social security numbers are generated from the repository only. When a lifeform sustains a casualty and is assigned a treatment brief, JDLM represents the consumption of the class VIII required, and if the medical unit does not have the required supplies does not treat the casualty. JDLM contains the capability to represent WIA, illness, general injury sustained in a non-combat environment, KIA, and death occurring due to natural or non-combat occurrences. The treatment report for the user contains the specific treatment brief and a list of events associated with the progression of the casualty, Figure 42. Casualties in JDLM are generated by user input through consumption events.

The screenshot shows the 'Personnel Events' window in JDLM. The top section is a table of personnel with columns: SSN, Name, LIT/AMB, Medical Unit, Assigned Unit, Condition, Treatment, and DTG Injury (Z). The bottom section is a table of events with columns: View, Event Time (Z), Entry Reference, and Message.

SSN	Name	LIT/AMB	Medical Unit	Assigned Unit	Condition	Treatment	DTG Injury (Z)
999711218	Zamora, Rodolfo	LIT		2 SQD TOW WPHS 18H1MAR		DED	252231ZApr2019
993029022	Serrano, Simon	LIT		2 SQD TOW WPHS 18H1MAR		DED	252231ZApr2019
996641190	Daugherty, Sam	LIT		2 SQD TOW WPHS 18H1MAR		KIA	252231ZApr2019
996410407	Hames, Ward	LIT		2 SQD TOW WPHS 18H1MAR		DED	252232ZApr2019
992668654	McBride, Colin	LIT		2 SQD TOW WPHS 18H1MAR		DED	252232ZApr2019
998443751	Barr, Harold	LIT		B CO 3AAVBH		DED	252236ZApr2019
992048805	Weber, Herbert	LIT		A CO 3AAVBH		DED	252237ZApr2019
993562551	Hanson, Kip	LIT		A CO 3AAVBH		KIA	252237ZApr2019
995046640	Santos, Simon	LIT		A CO 3AAVBH		KIA	252237ZApr2019
996321625	Zamora, Paul	LIT		A CO 3AAVBH		KIA	252237ZApr2019
990702394	Leonard, Joaquin	LIT		B CO 3AAVBH		KIA	252236ZApr2019
992867706	Golden, Paul	LIT		B CO 3AAVBH		DED	252236ZApr2019
993796845	Holt, Frederick	LIT		B CO 3AAVBH		DED	252236ZApr2019
993668665	Whitehead, Bernard	LIT		A CO 3AAVBH		KIA	252237ZApr2019
998152814	Hogan, Blaine	LIT		A CO 3AAVBH		KIA	252237ZApr2019
995294283	Hemel, Bradford	LIT		A CO 3AAVBH		DED	252237ZApr2019
997706863	Klaus, Thomas	LIT		A CO 3AAVBH		DED	252237ZApr2019
991191964	Clarke, Fenton	LIT		A CO 3AAVBH		KIA	252237ZApr2019

View	Event Time (Z)	Entry Reference	Message
1	252237ZApr2019		External ID U0000ENVXJ originated from unit M21822:A CO 3AAVBH
2	252237ZApr2019	PERS TP	Available for Movement
3	252237ZApr2019		Medical casualty 'BATTLE' - inbound to medical unit Not Located

Figure 42. JDLM treatment briefs

d. JDLM Services Capability

During the scenario JDLM displayed the capability to represent personnel administration, postal, and mortuary affairs. Personnel conditions in JDLM are defined in the personnel repository, Figure 43, to represent required personnel movement due to non-combat requirements. Combined with the health services capabilities, JDLM provides full capability to stimulate personnel administration. The mortuary affairs repository processes KIA and other personnel death, Figure 43. When executing mortuary affairs, the information is processed through treatment briefs, Figure 42. Supplies associated with mortuary affairs are represented in the supply repository and are expended as casualties are processed. Postal services are stored in a separate repository, and, while the repository was contained in the scenario, it was not used during the scenario.

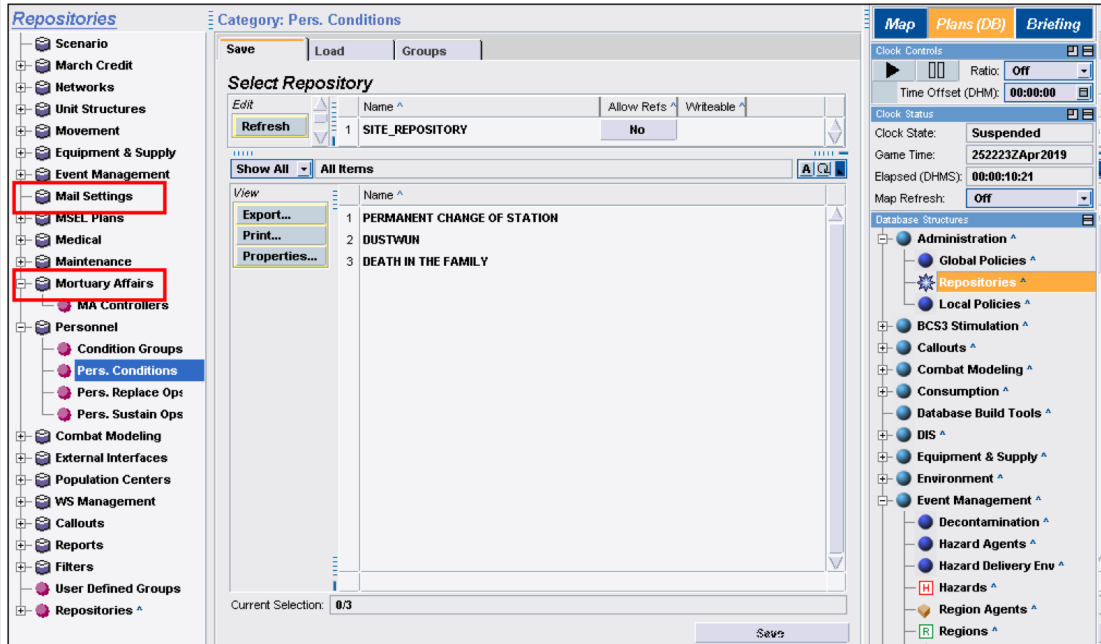


Figure 43. JDLM services capability

5. Summary of Findings

Of the three constructive simulations examined, JDLM contains the most useful and highest fidelity logistics data. However, as a standalone system it is not sufficient to meet MCLOG training requirements. To implement JDLM into the physical infrastructure requires a full overall of hardware and software install, furthermore, the training support staff requires re-training. This requires time and disturbance to the current training cycle. Furthermore, similar to JCATS, the repositories require alterations and expansions to match Marine Corps equipment and MCLOG specific requirement. Customization of the multiple databases in JDLM requires significant time allocation and experimentation.

The fidelity of logistics data is far superior to the current configuration of MTWS, and the information produced in JCATS. JDLM increases the supply data to include all classes of supply among other miscellaneous supply items commonly used in logistics operation. The maintenance capability is increased from basic classification to specific conditions including the supplies required for repair. Information specific to the equipment is increased from TAMCN to TAMCN and serial number. Health services information is

increased from basic classification to specific treatment conditions coupled with required supplies for treatment and triage. Information specific to the casualty is increased from generalized numerical data, to lifeform specific information. Services capability is increased from generic numerical data concerning personnel to detailed documentation including names, social security number, rank, MOS, blood type, gender, and religion. Furthermore, services are increased to include personnel administration, mortuary affairs, and postal.

The inability of JDLM to represent combat prevents simulations training. While it is possible to stimulate the GCE and ACE using consumption regions the operational picture is not reflective of real life, and a distraction to training. Furthermore, Marine Corps logistics is driven by the operations of the MAGTF, which includes combat and general maneuver. Consumption regions are not a sufficient substitute to a combat model.

V. FEDERATED ANALYSES

The federated analyses are structured into three segments established in Chapter III: federation implementation, federation behavior, and summary of findings. The logistics capabilities of each federation are a combination of the individual capabilities of each system discussed in Chapter IV, and established by the federation behavior. Thus, the specific logistic capability of each federation is not discussed, but the federation behavior is the focus of analyses.

A. HLA FEDERATION

Each constructive simulation, as a member of the JLVC federation, contains organic capability to pass information in accordance with the HLA standard. Therefore, HLA was used to federate the simulations mirroring the J7 JLVC federation.

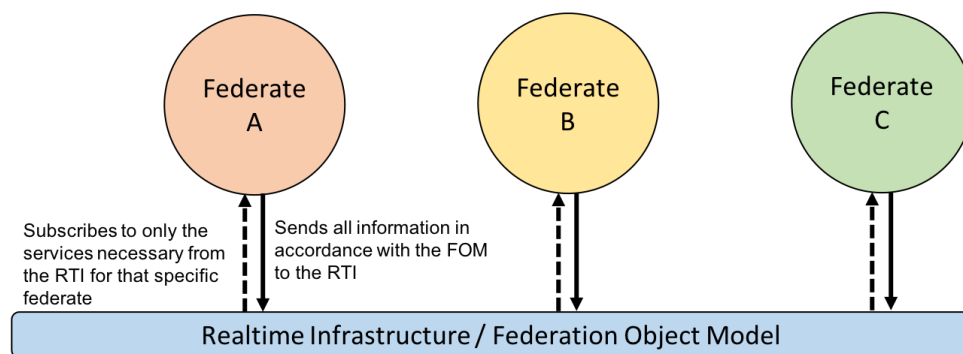


Figure 44. HLA configuration

HLA federations are linked through a common FOM and RTI stored and executed within each federate, Figure 44. FOMs and RTIs are either custom built for a specific federation or an existing standard approved by the Simulation Interoperability Standards Organization. The FOM and RTI used for these analyses are specific to the JLVC federation published by the J7. Information is sent in accordance with the FOM to the RTI from a single point within the federate. The FOM dictates a common language for the federation, establishing how objects and events are described and communicated through

an XML file (Dahmann et al., 2000). While federates identify and describe objects and events within the synthetic environment uniquely, the system is required to translate internal data into the HLA standard designated by the FOM. Information is passed across the federation through the RTI software running within each federate via an HLA bridge. The RTI not only collects all information from the federates, it provides a variety of services which filter data allowing the federates to subscribe to only the services specific to that federate (Dahmann et al., 2000). This customization for each federate prevents the system from becoming overloaded with useless information.

The OBS XML is used to establish all objects within the federation and which federate owns each object. HLA federation standards require that objects are controlled, or owned, by a single federate (Dahmann et al., 2000). Furthermore, it is required that object ownership is dynamically transferable from one federate to another while operating within the federation (Dahmann et al., 2000). All federates receive updates concerning object information via the RTI, however, only the owning federate publishes information concerning a specific object. Similar to the FOM and RTI, a single OBS XML force layout is used across federates ensuring the same STARTEX data is imported to each system.

The constructive simulation lab was used to create the two federations analyzed within a closed network. The FOM and RTI used in both analyses were acquired from the J7 via the JTDS. The two OBS XML files for each analysis were developed in the same manner as described in Chapters III and IV, with specific variations described below.

B. JCATS FEDERATED WITH JDLM

The JCATS JDLM federation was establish through the JCATS HLA bridge and the JLDM HLA listener, Figure 45. The JCATS workstation published directly to the RTI through the JCATS HLA bridge, and the JDLM workstation published indirectly through the JDLM HLA listener.

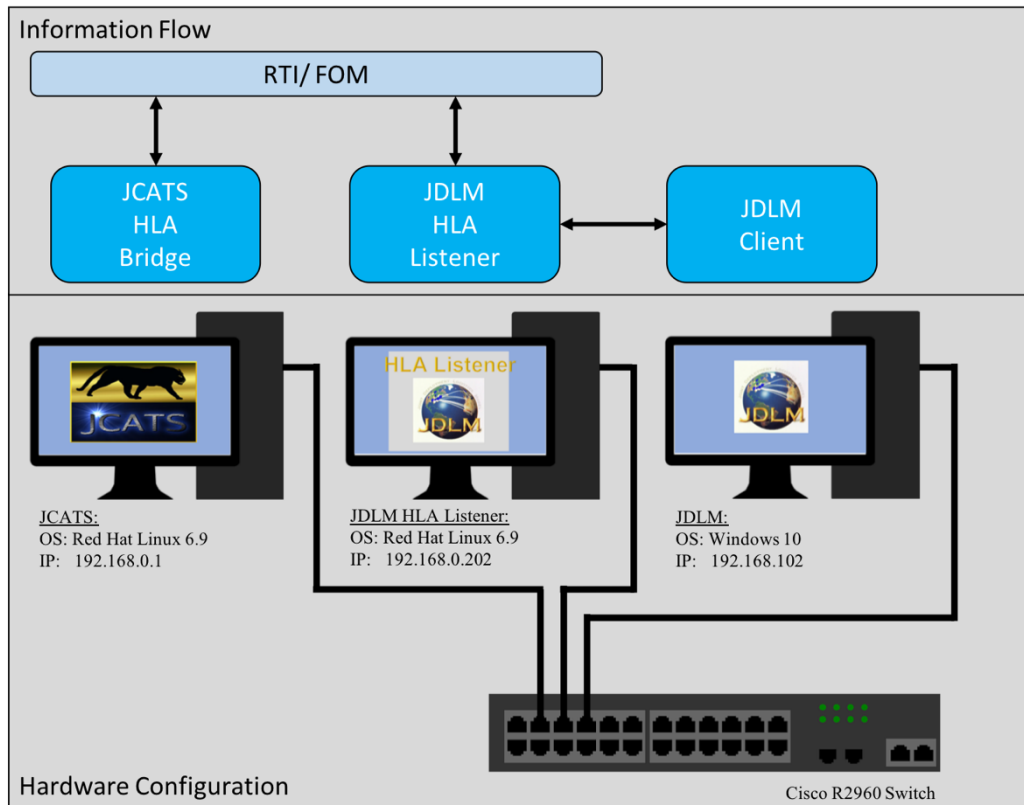


Figure 45. JCATS JDLM federation configuration

1. Federation Implementation

The JCATS JDLM federation was established using a ten-step process, listed below.

1. Alterations to the OBS for system specific requirements and ownership.
2. Import OBS XML as STARTEX data into each system.
3. Establish transfer nodes in JDLM.
4. Adjust the federation settings in JDLM.
5. Start the JDLM HLA listener.
6. Link the JDLM workstation to the listener through the JLVC gateway to join the federation.

7. Run JDLM.
8. Start the JCATS HLA Bridge to join the federation.
9. Confirm JDLM has received publication of objects from JCATS.
10. Run the scenario in JCATS.

The OBS XML used in the federation assigned ownership of the six maneuver elements to JCATS and the four logistics units were assigned to JDLM, Table 6. To build the federated OBS XML the individual JCATS OBS was altered by changing the ownership of the logistics units to JDLM through the mass editor as describe in Chapter IV.

Table 6. JCATS JDLM federation object ownership

OBS Unit Ownership	
JCATS Units	JDLM Units
A CO 3AAVBN	SUPPLY PLT CLB11
B CO 3AAVBN	MAINT PLT CLB11
1 SQD TOW WPNS 1BN1MAR	MOTOR TRANS PLT CLB11
2 SQD TOW WPNS 1BN1MAR	HLTH SVCS PLT CLB11
A BTY 1BN11MAR	
VMA 542	

Importing the OBS XML into JDLM followed a similar pattern to the individual analysis, described in Chapter IV. The OBS XML was imported and the prototypes linked accordingly, however, instead of establishing consumption regions, logistics nodes were installed as transfer points, Figure 46.

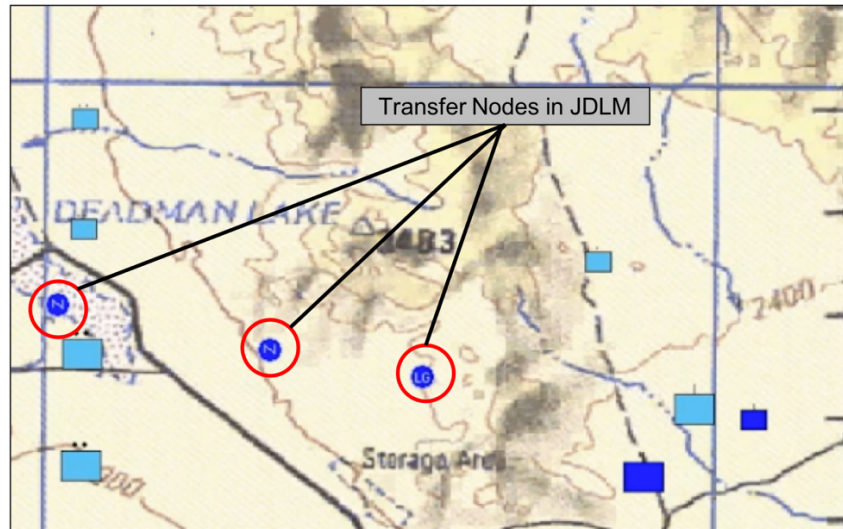


Figure 46. JDLM transfer nodes

In accordance with HLA standards, JCATS and JDLM are required to have the functionality to transfer objects, or in this case, entities. Entity transfer occurs via logistics nodes established within JDLM containing a specific logistics capability. During this federated analysis, a maintenance node, medical node, and personnel node were created. The maintenance node received all damaged platforms, the medical node received all wounded lifeforms, and the personnel node received all KIA lifeforms.

The final step in JDLM prior to joining the federation is adjusting the JLVC federation properties, Figure 47. JDLM has multiple functions that control the automation of entity transfers to support logistics and the display of entities owned by other federates. The specific functions used in the federated analysis are described below.

Description ^	Instance ^	Prefix ^	Auto-Maint	Min MCP (Km)	Maintena Timer (m)	CL VII Repla	CL VII Tir	Auto-Medic	Min Med (Km)	Medical Timer (m)	Perso Repla	Pers Rep Timer (m)	Rollup ^ Echelon	Play Federat Convoys	Mapped ^ Food NSN	Mapped ^ Water NSN
JCATS	1	JC	Yes	1000.0	1	Yes	1	Yes	1000.0	1	Yes	1	COMPANY	No		
JDLM	1	JD	No	0.0	60	No	60	No	0.0	60	No	60	COMPANY	No		

Figure 47. JDLM JLVC federation properties when federated with JCATS

- Auto-Offer Maint: This function allows JDLM to automatically offer transfer for platform entities damaged in in JCATS (Tapestry Solutions, 2016).
- Min Maintenance Control Point (Km): This sets a radius around the maintenance node that JDLM will offer automatic repair for JCATS platform entities damaged within that radius (Tapestry Solutions, 2016). The purpose of this function is to provide flexibility in automation. The user can adjust the requirement of supported units to evacuate equipment to a specific point depending on the training objectives. As the objective of this analysis was to observe the transfer behavior and collect logistics data, JDLM automatically offers repair to JCATS entities within one thousand kilometers of the node ensuring anything that was damaged during the scenario was transferred, Figure 47.
- Maintenance Timer (min): This is the simulation time JDLM waits before taking control of an entity which has been offered for repair (Tapestry Solutions, 2016). This function provides users a specific amount of time to account for a mistake or to register that an event occurred before transfer to JDLM. For this analysis JDLM is set to wait one minute prior to automatically transferring platform entities from JCATS, Figure 47.
- Auto-Offer Medical: This function allows JDLM to automatically offer transfer for casualty lifeform entities in in JCATS (Tapestry Solutions, 2016).
- Min Med (Km): This sets a radius around the medical node that JDLM will offer automatic treatment for JCATS casualty lifeform entities within that radius (Tapestry Solutions, 2016). The purpose of this function is to provide flexibility in automation. The user can adjust the requirement of supported units to evacuate casualties to a specific point depending on the training objectives. As the objective of this analysis was to observe the

transfer behavior and collect logistics data, JDLM automatically offers treatment to JCATS entities within one thousand kilometers of the node ensuring all casualties from the scenario were transferred, Figure 47.

- Medical Timer (min): This is the simulation time JDLM waits before taking control of a lifeform entity which has been offered for treatment (Tapestry Solutions, 2016). This function provides users a specific amount of time to account for a mistake or to register that an event occurred before transfer to JDLM. For this analysis JDLM is set to wait one minute prior to automatically transferring lifeform entities from JCATS, Figure 47.
- Rollup Echelon: The rollup echelon allows the users to set the unit display. For JCATS it is recommended the units are combined at the company level, Figure 47. (Tapestry Solutions, 2016).

After the federation properties are established in JDLM, the system is ready to join the federation by connecting with the HLA listener through the JLVC gateway configuration, Figure 48. The HLA listener contains the RTI as the direct connection to the federation. The JDLM JLVC configuration linking the client workstation to the listener contained the FOM to pass data. Following successful connection to the HLA listener, JDLM was placed into run mode for the playout of the scenario in JCATS.

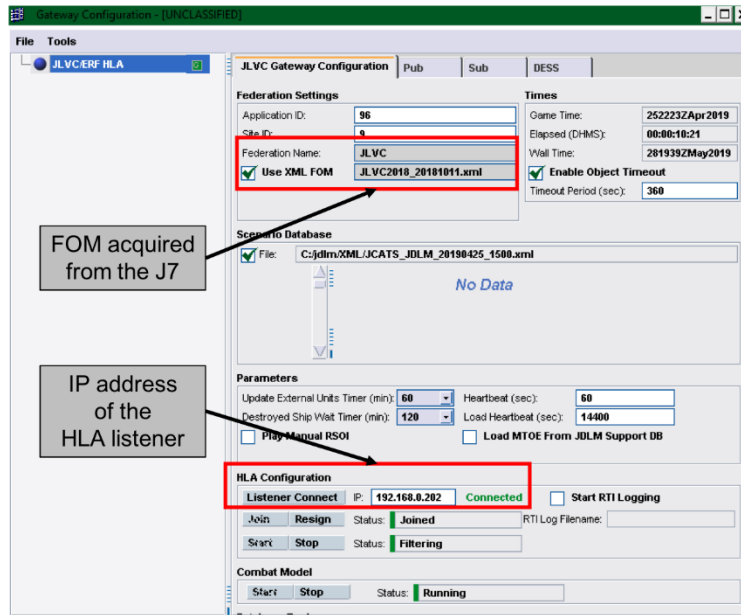


Figure 48. JDLM JLVCE gateway configuration

The OBS XML import into JCATS followed the same procedure as outlined in the JCATS individual analysis, Chapter IV. However, prior to starting the exercise the HLA bridge was established to join the federation. The HLA bridge configuration tool, allows JCATS to establish the HLA connection by storing the directories of the OBS XML, the FOM, and the RTI into a configuration file that the HLA bridge launcher utilizes, Figure 49.

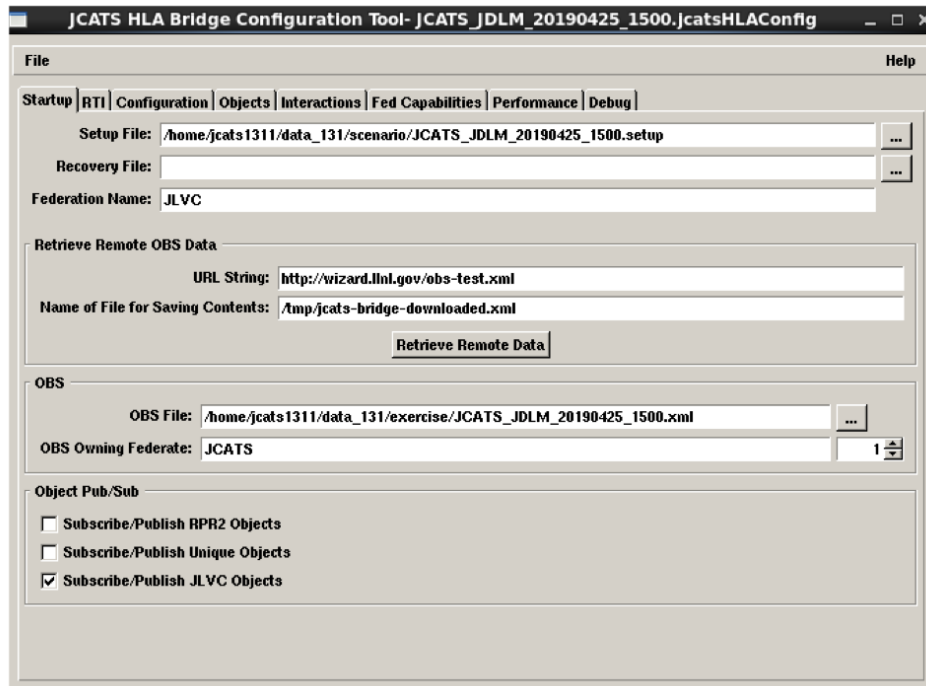


Figure 49. JCATS HLA bridge configuration tool

The bridge launcher uses the configuration file to join the federation and monitor the connection, Figure 50. JCATS publishes all information concerning owned entities to the federation as soon as the system has successfully joined the federation.

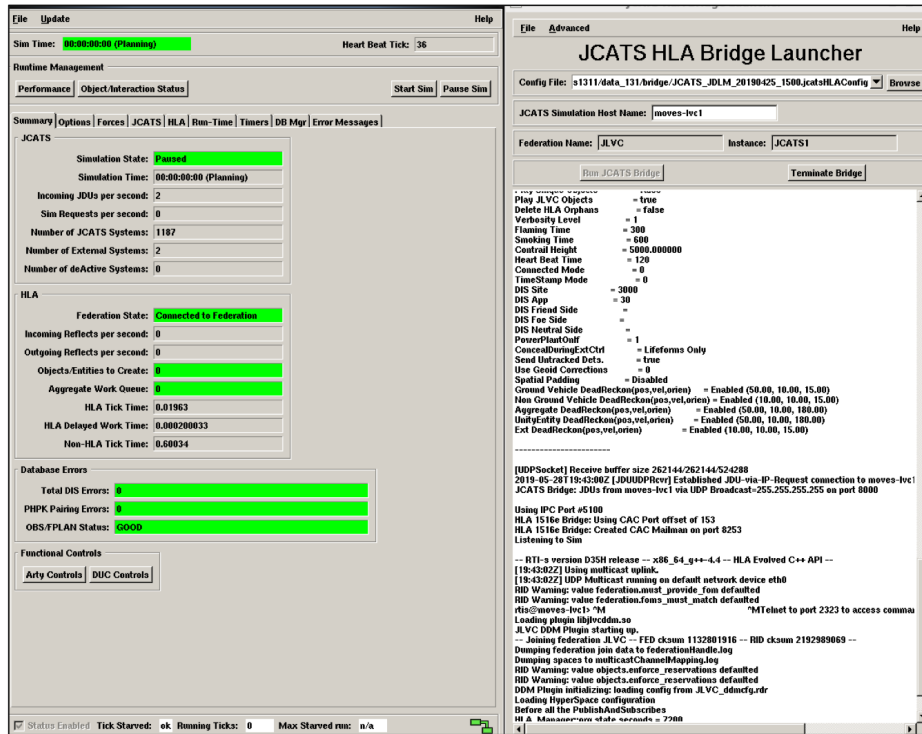


Figure 50. JCATS HLA bridge

To ensure fluid communication across the federation JDLM registers JCATS entities in the entities tool located in the JDLM plans database, and changes the RTI Object ID to reflect JCATS, Figure 51. With confirmation that JDLM is receiving JCATS information, the JCATS workstation is set to run, and the scenario is played out.

RTI Object ^ ID	External ^ ID	Publishing ^ Federate	Owning ^ Federate	Enum ^ Description	Location ^ (Milgrid)
JC/c0a80001/1000-U0000E0WRX	U0000E0WRX		JCATS	US M4	11SNT78649339
JC/c0a80001/1001-U0000E0WRY	U0000E0WRY		JCATS	US M4	11SNT78679339
JC/c0a80001/1002-U0000E0WS0	U0000E0WS0		JCATS	US M4	11SNT80649339
JC/c0a80001/1003-U0000E0WS1	U0000E0WS1		JCATS	US M4	11SNT80679339
JC/c0a80001/1004-U0000E0WS2	U0000E0WS2		JCATS	US M4	11SNT80679342
JC/c0a80001/1005-U0000E0WS3	U0000E0WS3		JCATS	US M4	11SNT80649342
JC/c0a80001/1006-U0000E0WS4	U0000E0WS4		JCATS	US M4	11SNT80619342
JC/c0a80001/1007-U0000E0WS6	U0000E0WS6		JCATS	US M4	11SNT80649539
JC/c0a80001/1008-U0000E0WS7	U0000E0WS7		JCATS	US M4	11SNT80679539
JC/c0a80001/1009-U0000E0WS8	U0000E0WS8		JCATS	US M4	11SNT80679542
JC/c0a80001/1010-U0000E0WS9	U0000E0WS9		JCATS	US M4	11SNT80639542

Figure 51. JDLM registering JCATS entities

2. Federation Behavior

During the exercise JCATS casualty play was turned off, and the automatic transfer of platform and lifeform entities was enabled in JDLM, as stated above. It is recommended that the casualty play in JCATS is disabled while federated to enable JDLM to adjudicate logistics requirements (Tapestry Solutions, 2016). By turning casualty play off, JCATS logistics data is reverted to generic data similar to the MTWS standalone capability described in Chapter IV.

JDLM tracked all unit movement and combat engagements that occurred in JCATS during the scenario, Figure 52. As combat occurred in JCATS, damaged entities were automatically transferred to JDLM for logistics diagnostics including repair, treatment, or mortuary affairs in accordance with the JDLM federation properties, Figure 52.

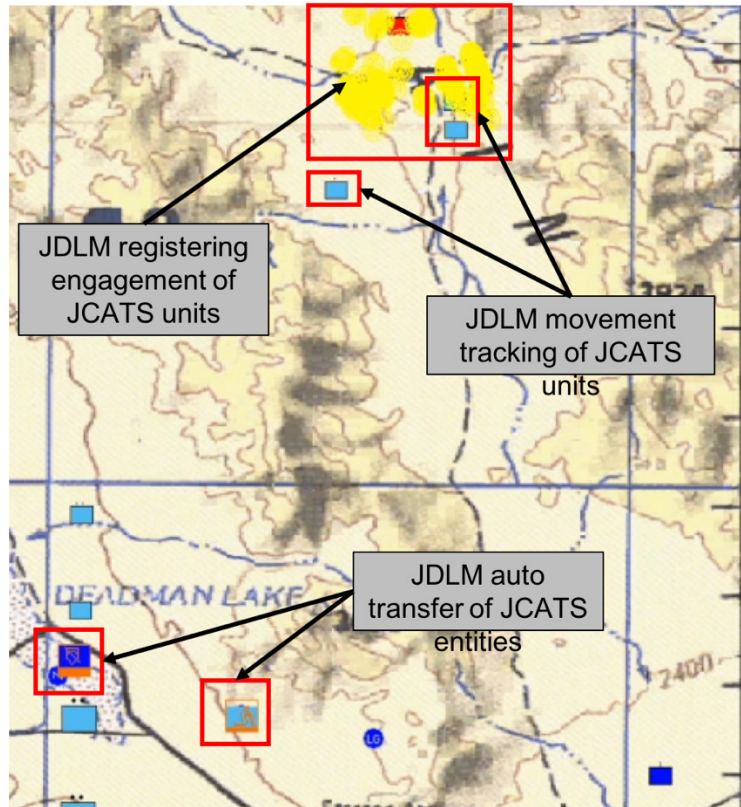


Figure 52. JDLM receiving JCATS federation data during the scenario

When entities were transferred to JDLM maintenance or treatment conditions were assigned, increasing the fidelity of the logistics data from generic in JCATS, to specific in JDLM. This sets the logistics capability of the federation as a combination of individual findings of JCATS and JDLM described in Chapter IV. JCATS handles the operational expenditure of supply classes I, III, and V, and the initial damage and casualty reports resulting from combat. JDLM is responsible for resupply, and establishing the specific logistics requirements of maintenance, health services, and services following the JCATS initial report. This division of effort between operational action and logistical response provides a complete view of the battle space for the training audience.

As entity level simulations, JCATS and JDLM publish information concerning all owned entities. This provides fluid information transfer across the federation and a clear operational picture for both JCATS and JDLM users. While the scenario was executed for

analysis, JCATS and JDLM maintained the same operational picture throughout, Figure 53.

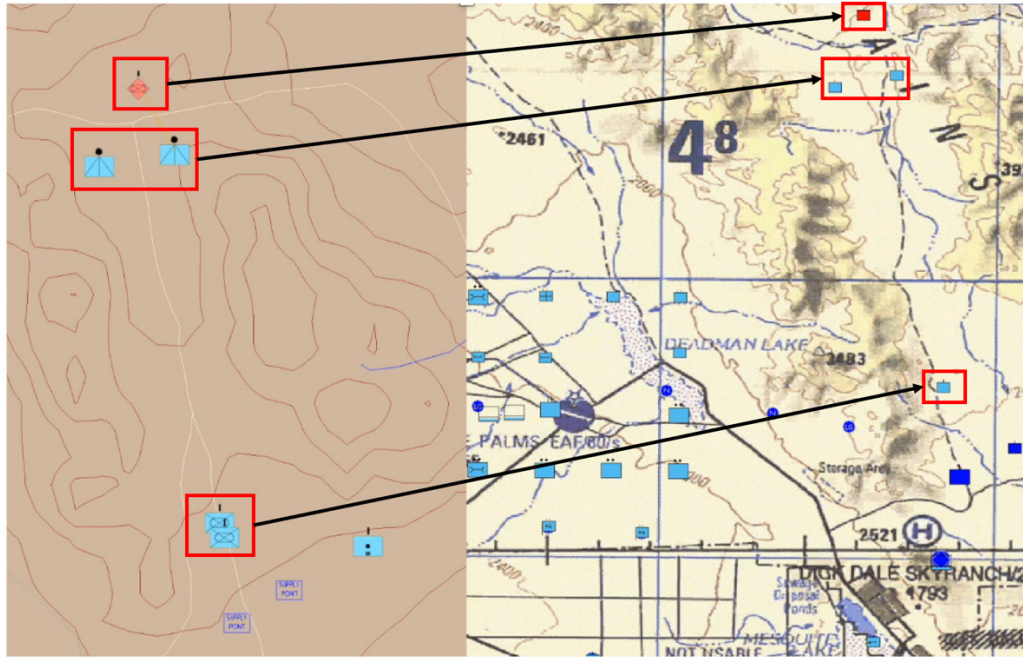


Figure 53. JCATS, left, and JDLM, right, operational picture while federated

3. Summary of Findings

The federation of JCATS and JDLM provides an increase in the fidelity of logistics data along with an increase in simultaneous training capability. An improvement to the current MTWS configuration, the logistics capability of the federation is a combination of the JCATS and JDLM logistics capability found in the individual analyses. To support simultaneous training across the MAGTF, the JCATS model contains sufficient data to simulate a logistics component of the ACE and GCE, while JDLM provides the information necessary to simulate the C2 of the LCE. However, the requirement to implement the configuration into the existing MCLOG infrastructure requires hardware and software overhaul of all systems, and training requirements for support staff. Furthermore, as discussed in the individual analyses of JDLM and JCATS, the data bases

of each system require adjustment to meet specific MCLOG needs. While the training capability is increased using the JCATS and JDLM federation, time and extensive training of personnel are required for implementation.

C. MTWS FEDERATED WITH JDLM

The MTWS JDLM federation was established through the MTWS HLA bridge and the JDLM HLA listener, Figure 54. The MTWS MAN published directly to the RTI through the MTWS HLA bridge controlled through the MSC. Similar to the JCATS JDLM federation, the JDLM workstation published indirectly through the JDLM HLA listener.

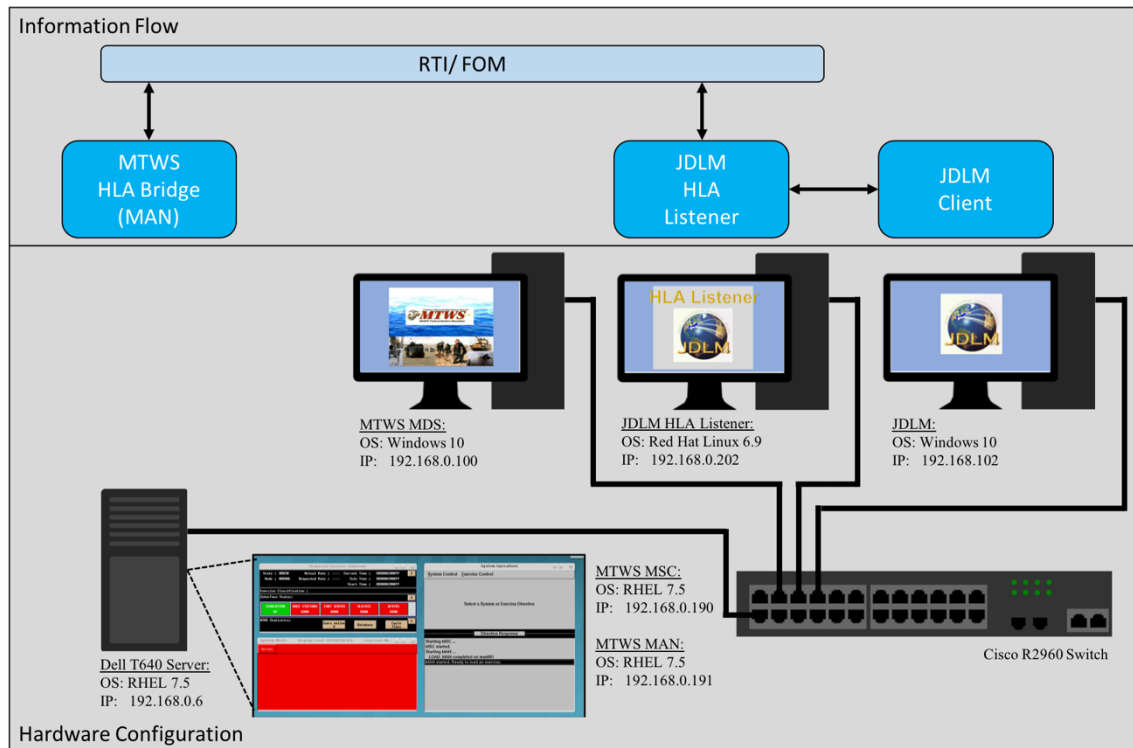


Figure 54. JCATS JDLM federation configuration

1. Federation Implementation

The MTWS JDLM federation was established using a ten-step process, listed below.

1. Alterations to the OBS for system specific requirements and ownership.
2. Import OBS XML as STARTEX data into each system.
3. Establish transfer nodes in JDLM.
4. Adjust the federation settings in JDLM.
5. Start the JDLM HLA listener.
6. Link the JDLM workstation to the listener through the JLVC gateway to join the federation.
7. Run JDLM.
8. Start the MTWS HLA bridge to join the federation through the MSC.
9. Confirm JDLM has received publication of objects from MTWS.
10. Run the scenario in MTWS.

The OBS XML used in the federation assigned ownership of the six maneuver elements to MTWS and the four logistics units were assigned to JDLM, Table 7. To build the federated OBS XML the individual MTWS OBS was altered by changing the ownership of the logistics units to JDLM through the mass editor as described in Chapter IV. The MTWS specific requirements for the OBS described in Chapter IV were maintained for the federated analysis.

Table 7. MTWS JDLM federation object ownership

OBS Unit Ownership	
MTWS Units	JDLM Units
A CO 3AAVBN	SUPPLY PLT CLB11
B CO 3AAVBN	MAINT PLT CLB11
1 SQD TOW WPNS 1BN1MAR	MOTOR TRANS PLT CLB11
2 SQD TOW WPNS 1BN1MAR	HLTH SVCS PLT CLB11
A BTY 1BN11MAR	
VMA 542	

The OBS XML was imported into JDLM as STARTEX data following the process outlined in Chapter IV. The OBS XML was linked to the JDLM prototypes from the baseline repositories, however, instead of creating consumption regions JDLM was configured to support the federation. Transfer nodes were established in JDLM following the same design outlined in the JCATS JDLM federation analysis. The nodes were established to support the transfer of objects concerning maintenance and medical requirements. MTWS transfers only platform and lifeform entities which can be repaired. Equipment classified as a catastrophic and casualties classified as KIA cannot be transferred to JDLM, therefore, a personnel node was not required to conduct mortuary affairs.

The MTWS JDLM federation does not contain the same flexibility in design as the JCATS JDLM federation when setting the JLVC federation properties in JDLM, Figure 55. While all objects in can be manually transferred by the user, MTWS federation functionality restricts the automation of transfer, described below.

Description ^	Instance ^	Prefix ^	Auto-Maint	Min MCP (Km)	Maintena Timer (mi)	CL VII Repla	CL VII Tir	Auto-Medic	Min Med (Km)	Medical Timer (mi)	Perso Repla	Pers Reg Timer (mi)	Rollup ^ Echelon	Play Federat Convoys	Mapped ^ Food NSN	Mapped ^ Water NSN
JDLM	1		No	0.0	60	No	60	No	0.0	60	No	60	COMPANY	No		
MTWS	1		No	0.0	60	No	60	No	0.0	60	No	60	ENTITY_ECHELON	No		

Figure 55. JDLM JLVC federation properties when federated with MTWS

- Auto-Offer Maint: MTWS does not contain the capability to allow JDLM to automatically offer transfer of damaged equipment. All transfers of platforms and lifeforms from MTWS to JDLM are conducted manually by the user.
- Min Maintenance Control Point (Km): Without the capability of auto-offer maintenance, this setting does not apply and is set to zero.

- Maintenance Timer (min): Without the capability of auto-offer maintenance this setting does not apply and is left at the default of 60 minutes.
- Auto-Offer Medical: MTWS does not contain the capability to allow JDLM to automatically offer transfer of WIA personnel. All transfers of platforms and lifeforms from MTWS to JDLM are conducted manually by the user.
- Min Med (Km): Without the capability of auto-offer medical, this setting does not apply and is set to zero.
- Medical Timer (min): Without the capability of auto-offer medical this setting does not apply and is left at the default of 60 minutes.
- Rollup Echelon: The rollup echelon allows the users to set the unit display. For MTWS it is recommended the units are combined at the entity echelon, Figure 47. (Tapestry Solutions, 2016).

After the federation properties are established, the JDLM HLA listener is started and the JDLM client is connected to the listener through the JLVC gateway. This process is the same as the description in the JCATS JDLM federation analysis above. Following the successful connection of the JDLM client to the HLA listener, the workstation has joined the federation and JDLM is set to run.

The process to import the OBS XML into MTWS as STARTEX data followed the procedure outlined in Chapter IV. The MTWS HLA bridge is established following the initialization of the force layout in the MSC, but prior to the simulation being placed in run mode. The MTWS HLA bridge is controlled through the MSC and executes the RTI through the MAN. To start the HLA bridge the FOM and OBS XMLs are loaded in the bridge settings, and the federation is joined, Figure 56. With confirmation of connection to the federation MTWS registers the system information and subscribes to the RTI, Figure 56.

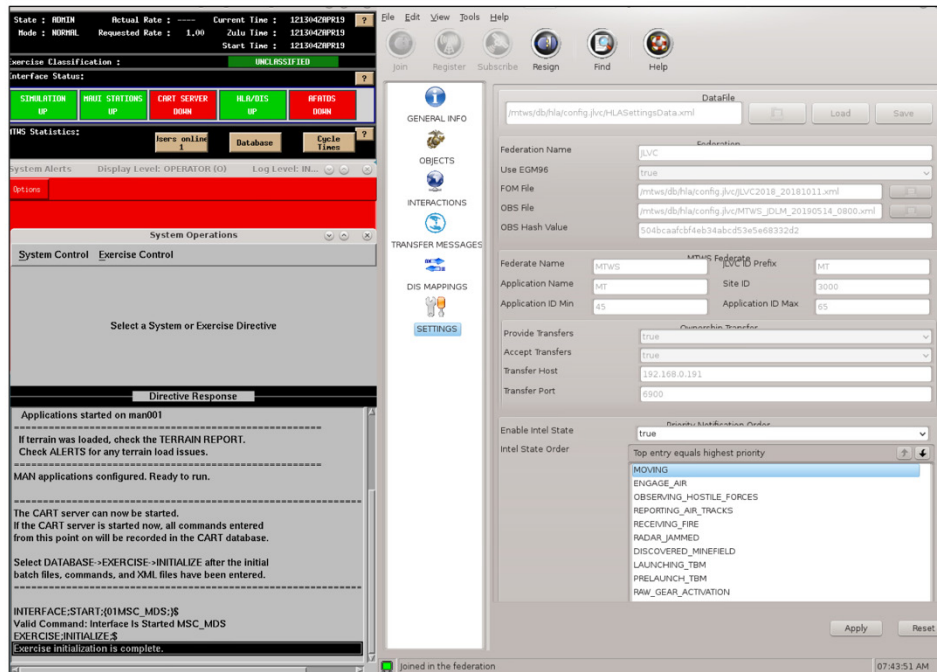


Figure 56. MTWS HLA bridge

To confirm communication between MTWS and JDLM in the federation, JDLM registers the published information from MTWS in the plans database entities report. This confirmation is not all inclusive, as generally MTWS only published the aggregate level information. However, when transfers are requested, MTWS publishes specific platform or lifeform information for JDLM to take ownership of, discussed below.

RTI Object ^ ID	External ^ ID	Publishing ^ Federate	Owning ^ Federate	Enum ^ Description	Location ^ (Milgrid)
MT/C0A800BF/U0000E2/U0000E2M9AW		MTWS	MTWS	US M4	11SNT90179434
MT/C0A800BF/U0000E2/U0000E2M9AX		MTWS	MTWS	US M4	11SNT90279441
MT/C0A800BF/U0000E2/U0000E2M9AY		MTWS	MTWS	US M4	11SNT90199440
MT/C0A800BF/U0000E2/U0000E2M9AZ		MTWS	MTWS	US M4	11SNT90129435
MT/C0A800BF/U0000E2/U0000E2M9B0		MTWS	MTWS	US M4	11SNT90149432
MT/C0A800BF/U0000E2/U0000E2M9B1		MTWS	MTWS	US M4	11SNT90139437
MT/C0A800BF/U0000E2/U0000E2M9B2		MTWS	MTWS	US M4	11SNT90199440
MT/C0A800BF/U0000E2/U0000E2M9B3		MTWS	MTWS	US M4	11SNT90219440
MT/C0A800BF/U0000E2/U0000E2M9B4		MTWS	MTWS	US M4	11SNT90239443
MT/C0A800BF/U0000E2/U0000E2M9B5		MTWS	MTWS	US M4	11SNT90229430
U0000E2M9B7	U0000E2M9B7		JDLM	US M4	11SNT88499000
U0000E2M9B8	U0000E2M9B8		JDLM	US M4	11SNT88499000
U0000E2M9B9	U0000E2M9B9		JDLM	US M4	11SNT88499000
U0000E2M9BA	U0000E2M9BA		JDLM	US M4	11SNT88499000
U0000E2M9BB	U0000E2M9BB		JDLM	US M4	11SNT88499000
U0000E2M9BC	U0000E2M9BC		JDLM	US M4	11SNT88499000
U0000E2M9BD	U0000E2M9BD		JDLM	US M4	11SNT88499000
U0000E2M9BE	U0000E2M9BE		JDLM	US M4	11SNT88499000

Figure 57. JDLM registering MTWS aggregates

2. Federation Behavior

During the scenario JDLM tracked the movement of the headquarters element of each unit and limited combat engagement from MTWS. Due to MTWS publishing information only concerning units at the aggregate level to the federation, the JDLM operational picture often did not match the operational picture in MTWS, displaying the lower echelon units separated from their headquarters element, Figure 58. The combat events registered in JDLM from MTWS were limited to only the close air support and indirect artillery fire.

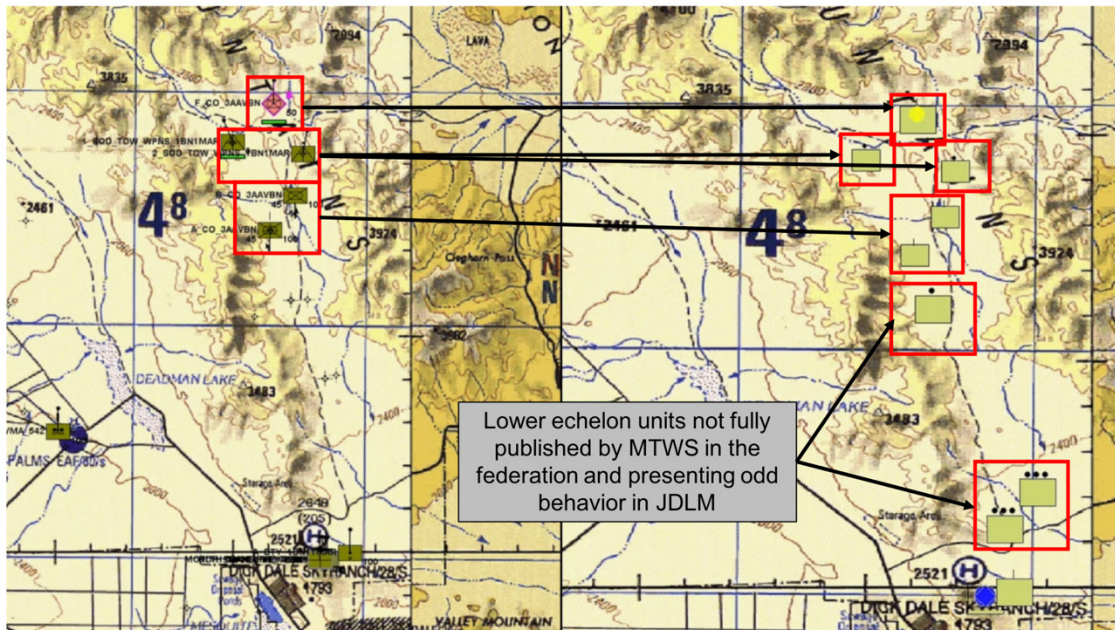


Figure 58. MTWS and JDLM federation operational picture

To transfer a specific platform or lifeform into JDLM following the engagement in MTWS, the user is required to conduct a casualty evacuation or unit movement to a transfer node and manually transfer the object through a command entry in the MDS. While the general publication of MTWS does not account for lower echelons, when MTWS conducts a transfer the lifeform or platform is identified as belonging to a specific unit under the aggregate level which JDLM identifies as a specific entity. When the transfer occurs and JDLM receives the item, a maintenance or treatment condition is established increasing the fidelity of logistics data.

The federation of MTWS and JDLM increased the fidelity of logistics data to include the supply, maintenance, and health services capabilities of JDLM. However, as KIA casualties are not transferred to JDLM, mortuary affairs and personnel administration capabilities remain limited (CESI, 2018). Similar to the JCATS JDLM federation, a combination of the two individual logistics capability is achieved through the MTWS JDLM federation. MTWS handles combat adjudication, the operational consumption of classes I, III, and V, and the initial maintenance and casualty reports. JDLM increases the fidelity of the initial reports concerning maintenance and health services, and provides

resupply capability. The division of logistics responsibility mirrors the difference between MAGTF operations of GCE and ACE, and the detailed requirements of the LCE.

3. Summary of Findings

The federation between MTWS and JDLM increased the fidelity of logistics data and the capability to train MAGTF logistics components simultaneously compared to the current MTWS standalone design. With the limited increase of fidelity concerning logistics services data, the MTWS JDLM federation contains less logistics fidelity than the JCATS JDLM federation. However, the requirement for implementation of the MTWS JDLM federation is far less time and training intensive than the JCATS JDLM federation. Adding JDLM to the existing MTWS infrastructure requires limited disturbance to the current training cycle and can be incorporated slowly to account for staff training requirements, and adjusting the JDLM repositories to fit MCLOG training needs. The unique capability of MTWS to represent MAGTF operations, combined with the logistics information stored in JDLM provide the opportunity to train various logistics components within the MAGTF.

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VI. CONCLUSION

A. MTWS JDLM FEDERATION RECOMMENDATION

Based on the three aspects of analysis, the recommended training alterations for MCLOG to conduct logistics C2 training is the incorporation of JDLM through an HLA federation with MTWS.

The current MCLOG infrastructure is designed to support MTWS as a standalone system utilized for both generating logistics data and stimulating C2 systems. The training support staff are familiar with MTWS and have had time to structure the parametric data based on specific MCLOG requirements. The JCATS JDLM federation contained only minor improvements in the fidelity of logistics data within mortuary affairs and personnel administration compared to the MTWS JDLM federation. The increase to training efficacy by switching to JCATS as a primary combat system does not overcome the disruption to the current training cycle, and the time required for full implementation of a JCATS JDLM federation. By maintaining the current infrastructure and adding JDLM, alterations can be made in conjunction with the training cycle with the use of JDLM increasing over time as staffs are trained and JDLM repositories are adjusted. Overall, the MTWS JDLM federation analysis resulted in the lowest estimated infrastructure alteration for implementation apart from the baseline.

The fidelity of logistics data is greatly enhanced by the incorporation of JDLM. The increase of supply classes from I, III, V, and VII represented in MTWS, to all classes of supply including blood products represented in JDLM. The increase of maintenance and health services information from a generic category in MTWS to a specific condition in JDLM. With MTWS limitation preventing the transfer of KIA and catastrophic equipment damage to JDLM, the increase to logistics data increases the logistics C2 training capability drastically.

The capability for a MTWS JDLM federation to support simultaneous training both laterally and vertically across the MAGTF is increased compared to the current training design. Both federated analyses resulted in similar simultaneous training, the MTWS

JDLM federation was selected based on the ease of implementation. By combining combat and logistics simulations MAGTF operations are represented for context through the combat simulation provided operational consumption rates. Specific logistics requirements resulting from MAGTF operation are generated in the logistics simulation providing the appropriate level of logistics fidelity for each logistics component.

Ultimately by federating two simulations with different strengths, the capability of the federation will exceed the capability of the individual simulations. As Marine Corps logistics is driven through tactical operation, it is required that a combat model produced the initial level of logistics data. To reduce the requirement on training support staff to generate higher fidelity data of use to a logistics C2 training audience, a logistics model is incorporated to automate the process.

B. RECOMMENDATIONS FOR MTWS FEDERATION FUNCTIONALITY UPDATES

The following updates to MTWS federation functionality are recommended based on observations from the MTWS JDLM federation analysis.

- Increase the publication data of MTWS to the federation to include lower echelon units.
- Increase the transfer capability of MTWS to include KIA casualties and catastrophic maintenance damage.
- Increase the federation capability of MTWS to include auto-offer maintenance, auto-offer medical, class VII replace, and personnel replacement within the JLVC federation properties in JLDL.

The federation behavior between MTWS and JDLM is not as fluid compared to the JCATS JDLM federation. In large part this is due to the transition from an aggregate simulation to an entity simulation. This is an issue that spans the DoD constructive simulation community, due to the level at which data is published within an aggregate simulation. By altering the publication to match the OBS XML force layout used in the federation, the issue can be mitigated.

The inability of MTWS to transfer KIA casualties limits the personnel administration and mortuary affairs that can be stimulated in JDLM, by enabling this transfer the logistics capability of the federation is increased. Furthermore, the logistics capability of the federation can be increased by enabling the JDLM features to include class VII and personnel replacement.

The auto transfer of platforms and lifeforms from MTWS to JDLM decreases the time requirement between the engagement of the operational unit and the generation of high-fidelity logistics data. By decreasing the time requirement for detailed logistics data flexibility of training is increased. While it is important to keep humans in the loop and ensure evacuations of personnel and equipment are rehearsed, when the logistics C2 staff is isolated the most important aspect of training is the logistics data. The addition of the auto transfer functionality facilitates timely information and increase training capability.

C. FUTURE WORK

Suggested future work to establish the ideal use of constructive simulation to support logistics C2 training includes:

- The evaluation of a larger tactical scenario involving all six functions of logistics.
- A thorough analysis on aviation logistics requirement within the MTWS JDLM configuration to advance the concept of simultaneous training.
- A continue examination on MTWS transfer points to JDLM to test the limitations of transfer capability.

This research conducted a limited examination on the functions of logistics and focused primarily on the LCE C2 staff. To continue research, it is required that attention shift to larger scale exercises, other logistics components of the MAGTF, and the limits of MTWS JDLM interoperability.

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