PEO Soldier Simulation Road Map V
The MATREX Federation

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Executive Summary

Problem Definition The Army's Program Executive Office (PEO) - Soldier has the complex task of acquiring and integrating a system of soldier equipment that meets their mission requirements. In order to better assess trade-offs in different soldier architectures, they seek an improved simulation capability that better represents the individual soldier on the battlefield. No single model provides this capability. They are pursuing a strategy of integrating three different simulation models to take advantage of the strengths of each. These models are the Infantry Warrior Simulation (IWARS), One Semi-Automated Forces (OneSAF), and the Combined-Arms Analysis Tool for the 21st Century (COMBAT^{XXI}). In this year, the fifth year of their effort, they focused on a series of integration tasks. The most significant of these is the real-time dynamic integration of the models that allows them to share data and algorithms during a model run.

Technical Approach The approach to this modeling integration was to break down the overarching integration task into a series of discrete tasks that could be performed by model development teams involved in this project.

- Enable the models to communicate in real time, sharing data and algorithms using the High Level Architecture integration technology.
- Integrating the ability to model advanced body armor, thermal weapons sights, direct fire weapons, and detailed casualty assessment into the candidate models.
- Integrate the ability to model advanced command and control such as networked call for fire, soldier blue force tracking alerts, and soldier radio systems into the candidate models.
- Enable sharing of a common environmental model using OneSAF's Environmental Runtime Component.
- Enable sharing of common scenario data via the Military Scenario Definition Language.
- Enable scenario sharing using approved soldier scenarios from Training and Doctrine Command.
- Set up processes that enable analysis of PEO Soldier decision items using proper scenarios, doctrine, and underlying data.

Results Much of the focus and effort for this year's work was centered on developing a working federation using High Level Architecture. A decision was made early in the year to use Research, Development, and Engineering Command's (RDECOM) Modeling Architecture for Technology, Research, and Experimentation (MATREX) for integration. Their federation architecture was designed to support the Future Combat Systems program, so it had the greatest support for advanced communications and command and control interactions. Both IWARS and OneSAF had already done development to support the MATREX federation object model. Another decision was made early in the year to adopt model driven architectures (MDA) to drive simulation development. In this manner, high-level activity diagrams represented the battlefield concepts. These were used to assign activities to different simulation models. More detailed sequence diagrams showed how the federation handled these activities using the technical details of the run-time infrastructure and federation object model. This communication enabled the modeling teams to better focus their efforts on code development. It also enabled explanation of these interactions to those who could

not read the code. This aids verification and validation of the models, along with analysis. By the end of the year, the team had a working test scenario in which OneSAF controlled the vehicles and indirect fire elements, while IWARS controlled the dismounted forces moving into a village for a raid. This architecture supports analysis of the impact of soldier equipment, to include weapons, sensors, body armor, and communications gear, on the dismounted squad, along with their supporting mounted forces.

In addition to achieving a running federation, the modeling team achieved progress in the following areas as well:

- Detailed representation of body armor in IWARS, and rough representation in COMBAT^{XXI} .
- Agreement on data structures and algorithms required to represent casualties using detailed physiological models.
- Representation of call for fire, communications, and command and control within the federation.
- Use of OneSAF's environmental runtime component as a common terrain model.
- Use of the military scenario definition language as a common scenario representation.
- Agreement on a scenario for the upcoming year that will test the federation's analysis capabilities and improve the processes for model development and analysis.

Given the progress made this year in achieving a level of integration, next year's efforts will focus on maturing the federation to the point where it is useful for analysis. Key tasks to achieve this include time management and automatic federation start/stop in order to do batch runs. In addition, scenario data, input data, and output data will have to be managed closely. PEO Soldier must work with Training and Doctrine Command to develop approved scenarios and vignettes for analysis. Finally, verification and validation of the federation must be addressed. Successful completion of these analysis tasks will deliver PEO Soldier a capability to do quick-turn model runs in order to assess the impacts of different soldier architectures on mission performance.

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1 Background

The PEO Soldier Simulation Road Map is an effort by PEO Soldier to develop within the Army a capability to model the effects of soldier equipment on unit-level effectiveness - focused at platoon and below. This study is the fifth year of collaborative effort between Program Executive Office Soldier and the United States Military Academy (USMA) Operations Research Center (ORCEN). Previous studies have led this effort to where it stands today. During the first year, the ORCEN analyzed simulation requirements and recommended a 3-model approach integrating IWARS, OneSAF, and COMBAT^{XXI}. During the second year, ORCEN effort was focused on establishing a memorandum of agreement between the three modeling agencies and mapping soldier equipment lists into prioritized modeling requirements. In the third year of effort, the modeling agencies signed the agreements and started prioritizing their work into common environmental and scenario representations that would enable "soft" linkages between the models. In the fourth year, these "soft" linkages were achieved, allowing scenarios to be run in one model, stopped, passed to a second model, and run to completion. In year, five, as this report details, hard linkages were achieved allowing the models to exchange data during run-time.

In November of 2003, Brigadier General James Moran, PEO Soldier, commissioned the ORCEN to develop a model, or family of models, that would support PEO Soldier decision making with respect to soldier equipment. The ORCEN, working within the PEO, further defined the need as, "PEO Soldier needs a simulation that allows the evaluation of platoon effectiveness based upon changes in Soldier tactical mission system (STMS) characteristics." Fulfillment of this need would bring the PEO in line with the Army's Simulation and Modeling for Acquisition, Requirements, and Training (SMART) program. The SMART program "involves rapid prototyping using M&S [modeling and simulation] media to facilitate systems engineering so that materiel systems meet users' needs in an affordable and timely manner while minimizing risk (Army Modeling and Simulation Office, 2002). " Taking this need, the ORCEN evaluated a series of alternatives that ranged from creating a brand new simulation to adopting, in its entirety, and existing simulation. The team concluded that while developing a single model was cost and time prohibitive, no single existing model met the PEO's requirements. They recommended a federation of models including IWARS, OneSAF, and COMBAT^{XXI}. PEO Soldier accepted this recommendation and asked the ORCEN to lead the effort in building a team to develop this federation (Tollefson and Boylan, 2004).

While everyone understood the need for a federated modeling solution, the composition, type of integration, and level of detail for the federation were not so simple to agree upon. The ORCEN worked two parallel efforts from June 2004 until July 2005. First, they had to establish memoranda of agreement that would enable funding and collaboration within this project. This required significant negotiation between PEO Soldier, the Natick Soldier Center (developer of IWARS), PEO Simulation Training and Instrumentation (PEO-STRI - developer of OneSAF), and Training and Doctrine Command Analysis Center - White Sands Missile Range (TRAC-WSMR - developer of COMBAT^{XXI}). Second, they had to further refine the analysis requirements for the federation. In short, PEO Soldier did not have a list of analysis requirements; they had a list of equipment. The ORCEN worked with the PEO to categorize and streamline this list into a discrete set of modeling requirements that could be implemented by the members of the federation. Once these requirements were understood, it was easier for the modeling agencies to agree to develop these capabilities (Martin, 2005).

Given an agreement to work together, and a list of analysis needs, the next significant question is where to start. The modeling teams first came together under the signed agreements in 2005. However, there was not general agreement on the integration technology or on the initial analysis tasks. The ORCEN worked with the PEO to select from the list of analysis requirements, a very short list of equipment and associated analysis questions. Collectively, the group decided to begin effort on "soft" linkages.

1. Equivalent terrain representations for specific areas of common interest
2. Equivalent environments, as appropriate
3. Equivalent methodologies or utilization of the preferred methodology from one of the simulations, as appropriate
4. Equivalent algorithms, as appropriate
5. Equivalent data, as appropriate
6. Ghosting and/or proxies of entities
7. Time/event management
8. Development of behavior sets
9. Method to obtain appropriate behavior interactions between COMBAT^{XXI} and IWARS entities
10. The best way to keep proxy elements in complimentary model updated
11. Use of simulation specific capabilities/constructs
12. Usability of the combined simulation
13. Data output and analysis

Tab. 1: Model linkage framework.

In other words, the models in the federation would not exchange data during run-time. Instead, they would agree on a common terrain representation and a common scenario representation. Using these representations, different models would take over the scenario, run a portion of the fight, update the status of the combatants, then pass that information to another model. Under this approach, the team could get started more quickly, develop a working relationship, and work out challenges to an eventual "hard" linkage where the models exchanged data with each other during the run. A brief list of the elements of the model linkage framework developed by this effort is shown in Table 1(Boylan, 2006).

During May of 2007, in the fourth year of effort for this project, the modeling team achieved a "soft" integration of two models, IWARS and COMBAT^{XXI}, for a small room-clearing scenario, as shown in Figure 1. This was made possible by the agreement between all of the development teams to use OneSAF's Environmental Runtime Component for common terrain and environment representation. They also agreed to use the Military Scenario Definition Language (MSDL) to share scenario data. Using this integration, the ORCEN analyst was able to collect mission performance data for the simulation run using a 2x2 factorial design. In this case, he represented two different levels of body armor and night vision equipment (Kramlich, 2007). This proof-of-concept integration was a major step in the five-year history of this project. The three models, selected in year 1, came together with a common understanding of the analysis requirements, established in year 2, and a common picture of the integration requirements, established in year 3. Most important in this successful linkage was the working relationships developed by the modeling teams and their commitment to the tasks at hand.

The successful proof-of-concept integration laid the groundwork for the 2007-2008 tasks for the Simulation Road Map. This work is the springboard for the academic year 2007-2008 tasks, bringing the federation closer to a federated analysis capability.

One of the products of last year's study was developing a consensus and task list to support work for the following year. The task lists in ANNEX A highlight those efforts for each component model.

2 Systems Engineering Process for the Development of Federated Simulations from Operational Requirements

The success of last year's file-based integration enabled the focus of this year's effort to be on the development of a real-time "hard" linkage between the models - a federation. Prior to proposing this effort, the ORCEN solicited the assistance of the Virginia Modeling, Analysis, and Simulation Center (VMASC) for their expertise and research in federation development. Key integration technologies such as high-level architecture, the federation development process, conceptual interoperability, and

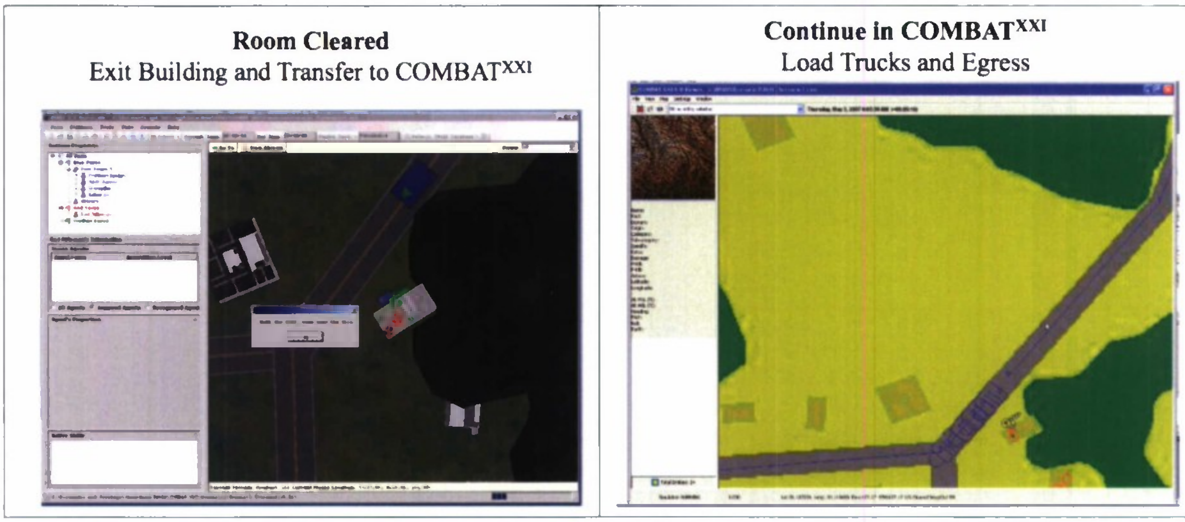

Fig. 1: File-based integration between IWARS and COMBAT^{XXI}.

model driven architectures were investigated.

This section documents the process and summarizes some necessary requirements to apply a systems engineering process to align acquisition, development, testing, training, and operational support for PEO Soldier. The systems engineering process proposed in this section is based on several relevant and community accepted methods and standards. These methods are reviewed in order to root the proposed process in already accepted work. The documented principles should support extending this to other alternatives as well.

These ideas generalize well to other systems acquisition problems. Currently, acquisition, development, testing, training, and operational support are only loosely coupled. The approach recommended in this report allows the reuse of significant findings, operational requirements, and constraints bridging the phases of the systems lifecycle. This results in better aligned support for the warfighters' needs.

2.1 Relevant Methods and Standards

The necessity of applying systems engineering processes in support of system decisions in all phases of the lifecycle is nothing new. Also, to anchor such processes in the operational necessities defined by requirements is common procedure. What is innovative is the idea to use common artifacts in support of all phases of the useful lifecycle of systems in a consistent way, covering all aspects of the operational lifecycle. This starts with the identification of an operational gap, a certain capability that is required to implement doctrine. Once this capability is identified, the procurement and acquisition community has to decide if a new system should be introduced to deliver the function implementing the capability, or if an existing system can be improved to provide the functionality.

2.1.1 Developing Essential Tasks, Related Equipment, and Metrics

Truly integrated operations depend on a solid foundation of common elements understood between all participating partners and organizations. The current approach is to establish a mission essential task list (METL) that lists the operational tasks forces need to perform to doctrinally accomplish a given mission. These tasks may also be mapped to a common Universal Joint Task List (UJTL). Several separately initiated US DoD programs as well as some Homeland Security efforts are planning to base their metrics of performance on mission essential tasks. Within NATO, comparable efforts are undertaken, although the resulting task lists are not always well aligned between all nations. In all these efforts a military task is identified, and necessary capabilities to perform this task are captured. The targeted result is a list of mission essential tasks, related capabilities, and metrics to measure the performance. It should be pointed out that mission essential tasks should not be tightly coupled with a system or a capability implementation. The tasks should describe the conceptual capability which – at least in theory – can be delivered by several systems or system components.

These ideas are tightly connected with the Military Missions and Means Framework (MMF) (Sheehan et al., 2004). The context is defined by an operational environment, enemy missions and forces, and a friendly military mission. This mission requires set of mission essential tasks, other specified or implied tasks, required capabilities, and military means in terms of forces and equipment that are needed to conduct the mission. The MMF is therefore the operational view describing what operational nodes are needed and which operational activities are conducted. The systems, which are normally systems that have to be evaluated or that are under test, provide capabilities that implement the means needed to conduct a mission. This is consistent with the systems view of how missions and means are concretely instantiated.

In order to assure scientific evaluations based on experimentation, metrics are needed that specify what data is collected and how this data is used to define success or failure. In order to be able to conduct the evaluation, these task elements must be put into a meaningful operational context. This is done by setting them into the context of a scenario or a vignette. The focus of all these activities should be the evaluation of the system. It is also essential to track other capabilities and their relative changes based on the system to be evaluated, in particular when it comes to indirect or higher order effects. Therefore, the design process for setting up a scenario is as follows:

1. The essential tasks required to accomplish the mission form the initial task list.
2. A system is identified that provides the required capabilities for the mission essential tasks.
3. All the tasks that are conducted by the system in support of the required capabilities are added to the task list to be evaluated.
4. All effects that are influenced (higher order effects) by the system are also captured.
5. Operational vignettes or scenarios comprising all tasks on the task list (if necessary prioritized by operational effects) are defined.
6. Metrics are selected that capture the success of the mission, the effectiveness of supporting tasks, and the related effects achieved.

The result of these steps is a scenario or a list of vignettes that comprises all tasks, effects, and metrics needed to evaluate the system.

2.1.2 NATO Code of Best Practice for C2 Assessment

The North Atlantic Treaty Organization (NATO) Code of Best Practice for Command and Control (C2) Assessment was produced in order to facilitate high quality evaluations. It identifies several steps of an iterative process:

• In the initial phase, the team starts with the problem formulation and related high-level solution strategies. This corresponds with the question of what the system to be evaluated should do in support of which missions.

• In the second phase, three steps have to be conducted to refine the ideas of the initial phase. In this phase, the team identifies the human and organizational factors (the concepts to be evaluated, where they are, how they operate, etc.) and puts them into the context of a scenario. In addition, the measures of merit are decided. This phase deals with identifying the important concepts and processes, their role in a scenario, and how to measure success or failure.

• Only after the conceptualization is done, the implementation phase is conducted. The selection of methods and tools – such as simulation systems to use, or supporting tools for the evaluation – is one of the steps. As important as the tool selection is to ensure that the necessary data is available or can be obtained within the constraints of the project.

• Finally, risk and uncertainty management, including sensitivity analysis of proposed solution, is conducted before the project is summarized in the deliverables.

2.1.3 High Level Architecture for Simulation Interoperability

Once the necessary tasks are identified and appropriate performance measures are identified, the relative performance of alternative systems architectures must be determined. Simulation is a useful tool for estimating the effects, task performance, and mission effectiveness gained by employing alternative systems and strategies in order to accomplish a mission. Unfortunately, large-scale simulations that evaluate all the necessary metrics are often not available. The simulation architecture must be composed from existing models, possibly built for other purposes. The selection of contributing systems should be based on the simulated systems, their capabilities, and their ability to support the desired metrics.

High level architecture (HLA) is a series of standards developed to support re-usability and interoperability between simulation systems. Within the context of this study, IWARS was developed to model the dismounted squad-level fight. Both OneSAF and COMBAT^{XXI} were developed to model the combined arms fight. Re-usability of and interoperability among these systems enable the components of one model to be used by other models. In a federated case, IWARS does not have to independently develop combined arms representations, and OneSAF and COMBAT ^{XXI} do not have to develop high resolution dismounted representations. At a basic level, in order to be HLA compliant, a federation (group of inter-operating models) and its federates (individual models in the federation) must comply with ten HLA rules (IEEE-SA Standards Board, 2000). The federates interact via a run-time interface (RTI)(Board, 2000b) using object models specified in accordance with the HLA object model template (OMT)(Board, 2000a). Because HLA supports time management via the RTI, it is a good choice for federations developed for large run sets and analysis.

2.1.4 FEDEP and SEDEP Processes

HLA standards documents are technically oriented. They ensure that, when the work of federation development is done, assuming all parties have followed the HLA rules, the simulations will interoperate technically. While this technical interoperability is a necessary condition for a working federation, it does not guarantee that the federation will sufficiently portray the simulated domain so that the analysis question can be answered. The Simulation Interoperability Standards Organization (SISO) recognized this problem and developed the HLA Federation Development and Execution Process (FEDEP), to address it (IEEE Computer Society, 2003). This process is a systems engineering approach which provides a top-down view of the federation. It superimposes a process and management plan to ensure that the developed federation is not only technically correct, but also meets the objectives for which the federation was developed in the first place. The Euclid RTP 11.33 description of the Synthetic Environment Development and Exploitation Process (SEDEP) is a similar process, because the FEDEP was used as a guideline when the SEDEP was developed. The necessity to build a strong conceptual model before going into the technical details is emphasized in both approaches.

- The SEDEP starts with an explicit User Needs Analyses, that is not supported by the FEDEP. The following steps are well aligned, as the SEDEP understands itself as an enhanced

FEDEP. One of the enhancements is the support of a common repository for all produced artifacts.

- The development process starts with refinements of the user requirements that lead to operationally driven federation system requirements for the SEDEP. On the FEDEP side, defining the federation objectives and developing a conceptual model for the federation are the counterparts.
- Based on this operational understanding, the federation is designed, implemented, integrated, and tested in both process models. In both models, the selection of federates is based on the operational requirements.
- Finally, the federation is operated, which means that the federation is executed and respective results are prepared. The SEDEP explicitly ends the process with performing an evaluation, which is partially integrated into the execution phase of the FEDEP.

Both process models clearly show the primary importance of operational requirements. Both make technical recommendations, but the implementation details are left to the model developers. Additional guidance is needed to ensure that the technical integration agrees conceptually with the operational viewpoint from which the federation requirements were developed.

2.1.5 Levels of Interoperability

At the core of PEO Soldier's integration challenge is achieving a level of interoperability that goes beyond simply ensuring that the models can share data and interactions. The modeled entities represent real-world people or systems, and the details of the model must be sufficient to capture the relevant aspects of PEO Soldier's decision problems. Building federations under these conditions requires more than a simple technical understanding of how simulations

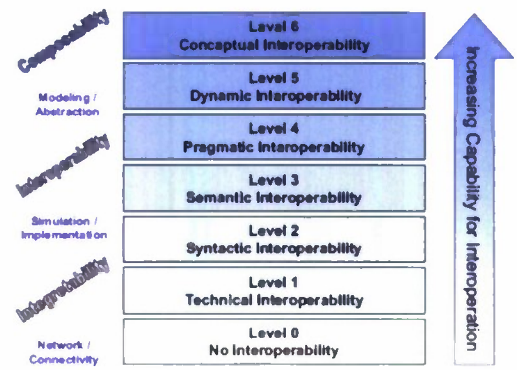

Fig. 2: Levels of interoperability.

exchange data. It requires a common shared conceptual understanding of the simulation environment, entities in the models, and exchanges between them. It is very difficult to gain this by simply looking at source code and conforming to technical standards. Levels of interoperability shed some light on this challenge (Tolk et al., 2006). These levels, shown in Figure 2, are arranged in increasing levels of abstraction. For example, technical interoperability, on the bottom level, is a very specific set of protocols that clearly define the standards. Conceptual interoperability, on the highest level, is a loosely defined by shared concept that provides context and common organizational uses for the models.

For composable models, the development team must have this shared conceptual model prior to detailed engineering of the federation. The FEDEP process includes this federation conceptual model as a product of step 2, but it does not prescribe useful tools or processes for developing and distributing this conceptual model. Fortunately, the software engineering community has defined a framework to support this level of interoperability - Model Driven Architectures.

2.1.6 Model Driven Architectures

The Object Management Group's Model Driven Architecture (MDA) is an open standard that enables

Level of Interoperability	Applicable tool
Conceptual Interoperability	DoD Architecture Framework artifacts Military Mission to Means Framework Platform Independent Models of the Model Driven Architecture
Dynamic Interoperability	Ontology for Services UML artifacts DEVS
Pragmatic Interoperability	Taxonomies Ontology UML artifacts, in particular sequence diagrams DEVS
Semantic Interoperability	Common reference models, such as C2IEDM Dictionaries Glossaries Protocol Data Units: Real-time-Platform Reference Federation Object Model
Syntactic Interoperability	XML HLA Object Model Template Interface Description Language
Technical Interoperability	Network and connectivity standards, such as HTTP, TCP/IP, UDP/IP, etc.

Tab. 2: Applicable tools for each level of conceptual interoperability.

an organization to specify their domain expertise in a modeling language that is independent of the technology used to implement that logic (Object Management Group, 2007). This specification achieves the technical goal of abstracting the domain logic away from the technical implementation details. For a simulation model, this supports validation of the model by domain experts to enable composability.

The underlying idea is to separate business and application logic from underlying technology. To enable this, MDA defines artifacts based on the Unified Modeling Language (UML) to describe a hierarchy of models that cope with the various challenges on different levels. Guidelines for the use of MDA establish three different modeling viewpoints (Object Management Group, 2003a), and these can be interpreted for the simulation domain.

- The highest level of abstraction is the Computer Independent Models (CIM). This is a conceptual model that identifies the concepts and processes important on the business level. This is easily mappable to the missions and means identified on the operational level. The main artifacts are use cases.
- The Platform Independent Models (PIM) capture concepts and processes in software engineering artifacts of class and object hierarchies, activities, sequences, and other means showing the roles of each component. PIM are very close to conceptual models that already use vignette and scenario elements motivating the various possible actions and their sequencing.
- If this conceptual model is mapped to a concrete platform and implementing language, middleware to be used, etc., the result is a Platform Specific Model (PSM). In the optimal case, the PSM can be used to produce code, as all information needed is available.

It should be pointed out that the models in the different layers are not developed independently from each other. Every use case of the CIM must be represented in form of sequenced actions engaging the roles as concepts in the PIM. The conceptual ideas of the PIM must be mapped to implementing entities, their capabilities and associations, and supporting interfaces on the PSM level. In theory, this is supported by the use of defining patterns. If the supporting middleware has an equivalent alternative, this approach allows to switch between representing PSM without having to change the PIM. In other words: A federation can be implemented using both middleware approaches alternatively. In the M&S business world, some M&S middleware and integration providers are utilizing this idea to support the migration between equivalent – or at least sufficiently close – implementations, such as supporting the Runtime Infrastructure interfaces defined in IEEE1516 as well as the alternative defined in version 1.3 NG (DoD).

MDA has the additional advantage of standardized meta-models. The Meta-Object Facility (MOF)(Object Management Group, 2002) and XML Metadata Interchange (XMI)(Object Management Group, 2003b) declare abstractions for the representation and exchange of models. These features of MDA, if applied for modeling and simulation, allow simulation system developers to take advantage of the numerous modeling and development tools that are available in the commercial and open source community based on these standards.

In order to support both composability and agility with respect to technical architectures, it seems that a formal modeling system for the simulation domain should have the following characteristics:

- It should allow different levels of abstraction, such as the CIM-PIM-PSM paradigm, so that domain experts can understand and validate the model without having to understand computer programming and information exchange details.
- The platform specific model should be executable to enforce a formal structure, but it should not require any unnecessary overspecification related to the technical implementation.
- The model should be able to be described using open standards so that simulation developers can take advantage of available tools that have evolved in the business community.

2.1.7 MATREX

In order to support greater interoperability between research and engineering models, the Army's Research, Development, and Engineering Command (RDECOM) established a program called the Modeling Architecture for Technology, Research, and Experimentation (MATREX)(Hurt et al., 2006). MATREX is an implementation of a unified Army federation to support distributed engineering-level analysis within a greater force-on-force environment. At the core of this architecture, MATREX provides a runtime interface (RTI), a FOM, and a middleware independent capability that allows simulation developers to move with agility from different implementations of HLA or Test and Training Enabling Architecture (TENA).

These capabilities are enabled by a set of components and tools. Key components include battle command management services which implement federation services for communications, situation awareness, and command and control. The Protocore tool is a simulation architecture development environment that allows federation developers to design a FOM and automatically generate source code for participating simulations that interact with that FOM in a middleware independent fashion. This capability is based on a transformation from a PIM specification, the FOM, to a PSM specification, such as HLA 1.3. In this sense, MATREX is a realization of MDA in support of federated simulation. The Automated Test Case capability allows federation developers to use an executable modeling interface to define the specifications for test cases that can be automatically generated and used to verify simulation implementations. Additional infrastructure support including initialization, data collection, and analysis are packaged within MATREX.

In this section, we identified that the MMF and METL support the operational analysis of what the relevant tasks are when a system needs to be evaluated. The result is a description of tasks in the context of vignettes or scenarios with applicable metrics. Operational requirements should also drive technical selection and integration. The NATO Code of Best Practice as well as the modeling and simulation standards FEDEP and SEDEP show which steps are needed to set up and execute a federation. Separating business logic and platform specification leading to a hierarchy of models allows the MDA to facilitate the migration between equivalent or closely related technical solutions. The MATREX program is a realization of these capabilities within the Army. In the next section, we will document a systems engineering process that integrates these ideas enabling the seamless management of federation development for system evaluation from the operational analysis to the technical details of middleware selection and interface design.

2.2 The Systems Engineering Process

The systems engineering process proposed in this report was motivated by the need to support project management with a consistent view of PEO Soldier challenges in compliance with relevant processes as described in the previous section:

- The essential tasks to be used for the evaluation should be identified to support the selection or development of relevant vignettes or scenarios.
- Simulation systems should be selected based on their ability to support the evaluation of these tasks. The simulated system capability should be the driver for the decision.
- The process should be applicable to evaluate alternatives for supporting simulation components and enable the project manager to make informed decisions.
- The federation of these simulation systems should be supported utilizing the best middleware available for the task. This decision should be driven by the functionality of the middleware and its necessity in the federation development process.
- The integration of systems and middleware should be supported to the maximal extent. The decisions of model integrators should be reduced to a minimum. This avoids ambiguity of interpretations. Existing solutions should be reused as much as possible.

2.2.1 Identifying Essential Tasks

In evaluations, operations and training, time and resources are always limited. It is necessary to concentrate the efforts on the essential tasks. For military operations, task lists are a way to support the decision makers in making the appropriate selection. If for example, the effect of a soldier radio is to be evaluated, then those tasks which make use of the radio must be included in the task list. Soldier communications tasks are an obvious example. In addition, command and control tasks which make use of information provided via radio communications must be analyzed as well. The result is a list of tasks in which the systems under evaluation play significant roles. This list is represented in form of use cases that identify the action performer, the action target, and the action itself. An example of a use case diagram supporting this effort is shown in Figure 3. This use case list can be supported by storyboards and organizational diagrams of the actors. These elements of the CIM are represented using UML. This CIM is the result of the first phase.

2.2.2 Setting the Tasks into Context: Building Scenarios, Vignettes, and Metrics

In the second phase, the actions of the use cases are combined to vignettes and scenarios. This allows definition of metrics for each of the tasks in the context of the operational environment. Initially, these products are in commonly understood language and graphics suitable for the domain to be simulated. In the case of the PEO Soldier simulation, An operational scenario was defined as shown in Figure 4.

The next step is to begin to transfer the operationally oriented descriptions into a computational context.

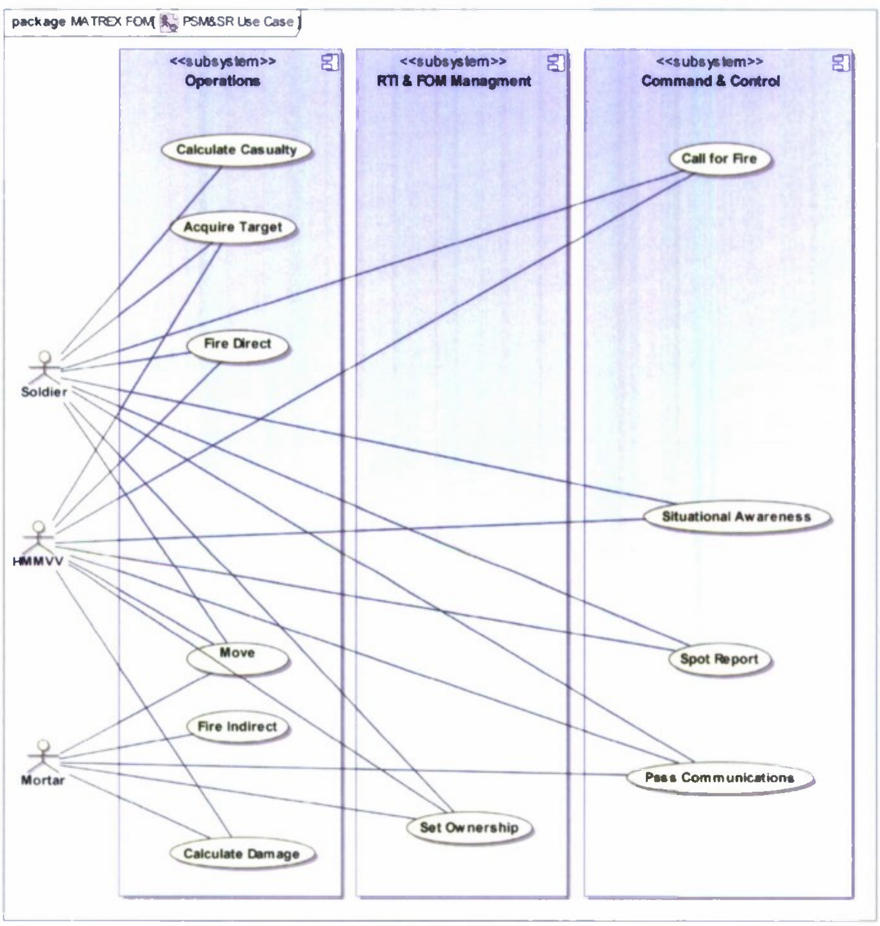

Fig. 3: Use case diagram for soldier scenario.

PEO Soldier Simulation Road Map
HLA Integration Scenrio

Situation. Based on intelligence from a local source, a US squad engaged in counter-insurgency operations has planned a raid to capture an insurgent leader in the town of Shugart-Gordon. Multiple sources of intelligence have confirmed the location of the leader at Additionally, they have reported that his cell members have stationed themselves on rooftops within the town to identify potential Coalition forces and provide early warning to their leader. They also have mortar support. The citizens of Shugart-Gordon have fled the village, and it is primarily used as an insurgent planning and training center.

Mission. 1/1/A/1-5CAV conducts raid at 011500MAY08 at 31.1057N 91.1193W in order to capture local insurgent leader and deny the use of Shugart-Gordon as a training sanctuary.

Execution. The purpose of this operation is to capture the local insurgent leader in order to gain further intelligence about insurgent operations. At the end of this operation, we would like to have the insurgent leader alive and in Coalition custody with no Coalition casualties. Because the citizens of Shugart-Gordon have fled the area, collateral damage is of little concern. 1st squad will conduct the raid with direct support from the mortar section. They will conduct the raid in three phases, mounted movement, dismounted movement, and clearing the objective. During the operation, one fire team will provide overwatch while a second fire team enters the objective building to capture the insurgent leader and clear it of enemy fighters. Mortar fires will be used to help clear rooftops of enemy fighters.

Execution Matrix				
Unit	Phase I - Mounted Movement	Phase II - Dismounted Movement	Phase III - Clearing the Objective	Phase IV - Egress
A Fire Team	Mounted in lead vehicle	Move to Dismounted SBF and provide overwatch to B TM's movement	From Dismounted SBF, provide overwatch to B TM's actions on Objective. Lift fires when B TM begins breach of door.	Provide overwatch to B TM's egress, then remount lead vehicle.
B Fire Team	Mounted in trail vehicle	Move along Dismounted Route to position near objective	Breach objective to capture insurgent leader and clear enemy fighters	Egress along dismounted route and remount trail vehcile
HMMWV Section	Move along RT Blue and drop teams at Mounted SBF	Provide overwatch from Mounted SBF	Provide overwatch from Mounted SBF	Upon mounting soldiers, egress along RT Blue
Mortars	Priority of fires to 1st Squad	Priority of fires to 1st Squad	Priority of fires to 1st Squad	Priority of fires to 1st Squad

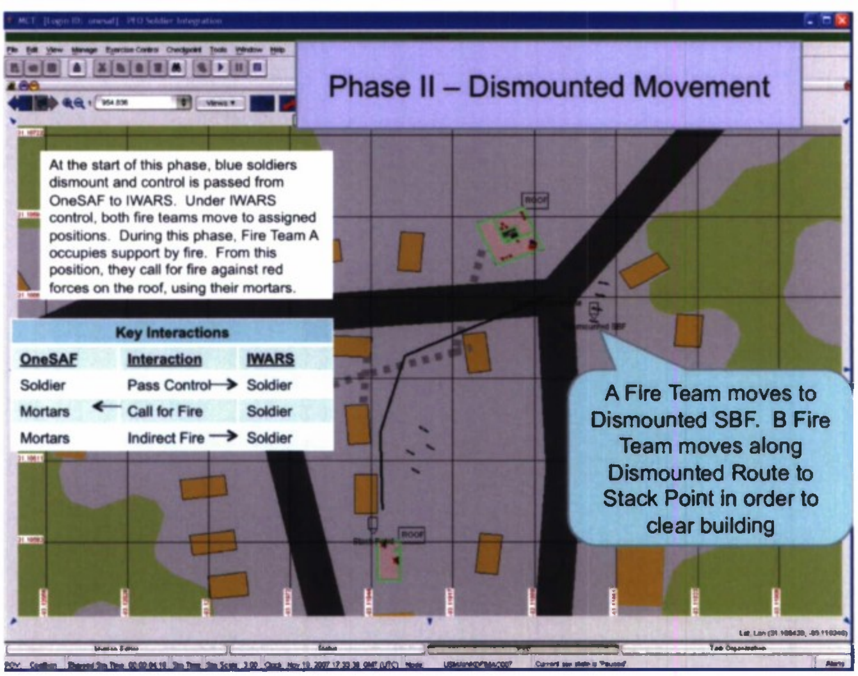

Fig. 4: PEO Soldier simulation scenario.

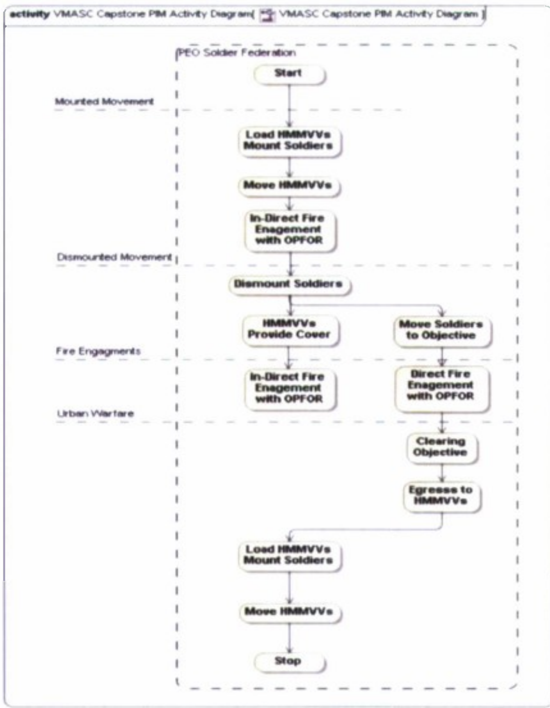

Fig. 5: Activity diagram depicting direct fire engagement tasks.

The resulting hierarchies are captured in UML, but they have been proven to support the communication with military experts as well. Figure 5 shows an activity model capturing the overarching tasks of the PEO Soldier simulation scenario. All tasks can now be described with metrics. Accuracy and resolution are decided based on military expertise, not on technical constraints. The result of this phase is a description of the scenarios or vignettes that should be used to evaluate the aspects of the system under test. An easy bookkeeping check can make sure that all use-cases of phase 1 are considered in at least one vignette. Also, each role must be mapped to an object. If a complete MDA approach is used for the support, all objects are converted into elements of the common warehouse meta-model (CWM), described by the Meta Object Facilities (MOF). This possibility, however, was not applied in the underlying project so far.

2.2.3 Identifying applicable Simulation Services

Up until this point, only operational requirements were used to define what should be used to evaluate a system. In this phase, the simulated systems and capabilities are used to identify applicable simulation systems. The requirement is that models must present their abilities in form of a PIM. The PIM defines a model's ability to model systems, capabilities, and activities. Concepts, properties, and processes need to be made transparent. The advantage of using UML artifacts is that it is possible to make the system transparent while protecting the intellectual property of technical details behind the implementation. These PIMs look very similar to the artifacts produced in the last phase.

Standardization across the armed forces will support alignment. In particular, organizations should name the same objects and processes identically and consistently, using these definitions to tag data describing the represented concepts, properties, and processes. Standards like the Military Scenario Definition Language (MSDL) and the Coalition Battle Management Language (C-BML) support potential solutions to this challenge. A common data administration of M&S and command and control would be helpful as well.

The result of this mapping process is the identification of simulation systems required to model each component activity in within the defined military context. These systems must also produce the required data for mission, task, and effects assessment. This process supports the following objectives:

- Minimize the number of supporting simulation systems that represent the scenario
- Minimize the costs of obtaining the simulation systems and supporting data
- Maximize the use of simulation system under governance of the project manager
- Maximize the acceptance of systems

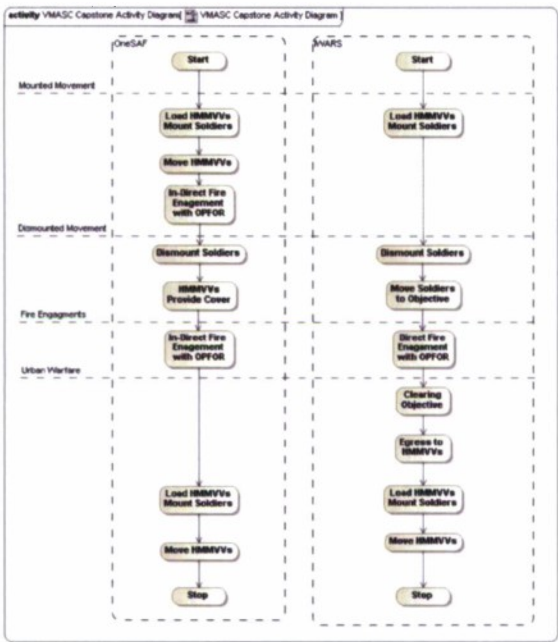

Fig. 6: PIM representation of PEO Soldier scenario with simulation system, shown as swimlanes, selected to model tasks.

Figure 6 shows a PIM representation of the PEO Soldier scenario with simulation systems identified to model each of the represented tasks.

2.2.4 Preparing the Federation

The result of the last phase can most easily be visualized as a PIM with swimlanes. Each object and each activity is aligned with the simulation system information that can be used to represent it. Some objects and activities represent general concepts, such as soldiers and tanks, and they are likely to be found in many systems. Other features are very special, such as waveforms for special communications, and only a few simulation system will provide them.

The PIM with swimlanes can now be used to support the decisions on which system should represent which objects and activities. This decision is triggered by the objectives enumerated at the end of the last subsection. The optimum for the analysis would be to maximize the coverage of operational requirements, but other constraints – such as time, funding available, or security concerns of model providers – can limit the feasible solution. However, no matter what motivates the ultimate selection of models, it is very likely that at least two models are selected that need to be federated to provide all necessary capability. Only in rare cases, everything is provided by one model, and no federation support is needed. Whenever an activity connects two objects hosted in different systems, or whenever properties needed to support the activities or the identified metrics for one object are provided by different systems, a federation is needed to handle the interactions and updates.

The patterns supported by MDA to move from PIM to PSM support integration with applicable middleware. Alternative middleware solutions can be supported, such as mapping to package data units of the IEEE1278 Distributed Interactive Simulation (DIS), or objects and related methods within the object model used by TENA. The use of web services is another option. Furthermore, mixed strategies can be supported, such as using the Extensive Markup Language (XML) file based MSDL for initialization, the HLA based update of attributes and sending of interactions for simulation based information exchange during runtime, and web service based information exchange with C2 systems based on C-BML.

Another more conservative application is the definition of stubs for information exchange requirements to be enhanced by the implementing simulation systems. If a future simulation shall replace one of the current systems, the interface does not change. In fact, the initial simulation can test the federation and perform preliminary analysis. When the replacement simulation is implemented, it federates using the same interfaces. The MDA pattern identifies exactly what elements and procedures, methods, and callbacks need to be supported.

To support the PEO Soldier scenario for this project, the following steps were performed.

1. PEO Soldier decided that the following essential tasks will be sufficient for a first evaluation:

transport in a HMMWV, direct fire engagement with insurgents on the top of a roof, clearing a house in search of at least one enemy inside, indirect and direct fire from hostile forces that will result in a call for fire to a supporting mortar unit.

2. The resulting scenario activities are captured in Figure 5. The resulting PIM could be used to identify two models that if used in conjunction provide the desired capability and metrics for PEO Soldier: One Semi-Automated Forces (OneSAF) and Infantry Warrior Simulation (IWARS). While OneSAF provides the frame for the scenario, IWARS provides the high-resolution models to evaluate the effects of soldier equipment such as body armor and night vision goggles.

3. The scenario activities were separated into OneSAF activities and IWARS activities. Wherever a crossover shows up, information needs to be exchanged. Figure 6 shows the activities side by side. This step is the equivalent of the PIM for federated simulation development.

4. PEO Soldier decided to base the on-line coupling of OneSAF and IWARS on HLA as the interoperability standard. They used the MATREX FOM for the information exchange model and MATREX tools for federation development. Therefore, the information exchange requirements resulting from the PIM mapping in step 3 had to be mapped to RTI calls and the use of classes and interactions with attributes and parameters defined in the FOM. For example, the "call-for-fire" activity had to be mapped to a "call for fire" interaction as defined in the MATREX FOM. The relevant object classes and interactions used to support the PEO Soldier scenario are shown in Figures 7 and 8.

5. Based on the activities identified in step 3 and the classes identified in step 4, sequence diagrams were developed that broke down the functional activities in the simulation into specific actions and communications for the federation using data elements from the MATREX FOM. Together, steps 4 and 5 of this process represent a detailed technical architecture for the federation that can be implemented using a specific interoperability infrastructure - HLA using the MATREX FOM and RTI. These represent the PSM for federated simulation. Figures 9 and 10 show sequence diagrams representing platform specific implementation of direct and indirect fire engagements from firers in one model engaging targets in another model.

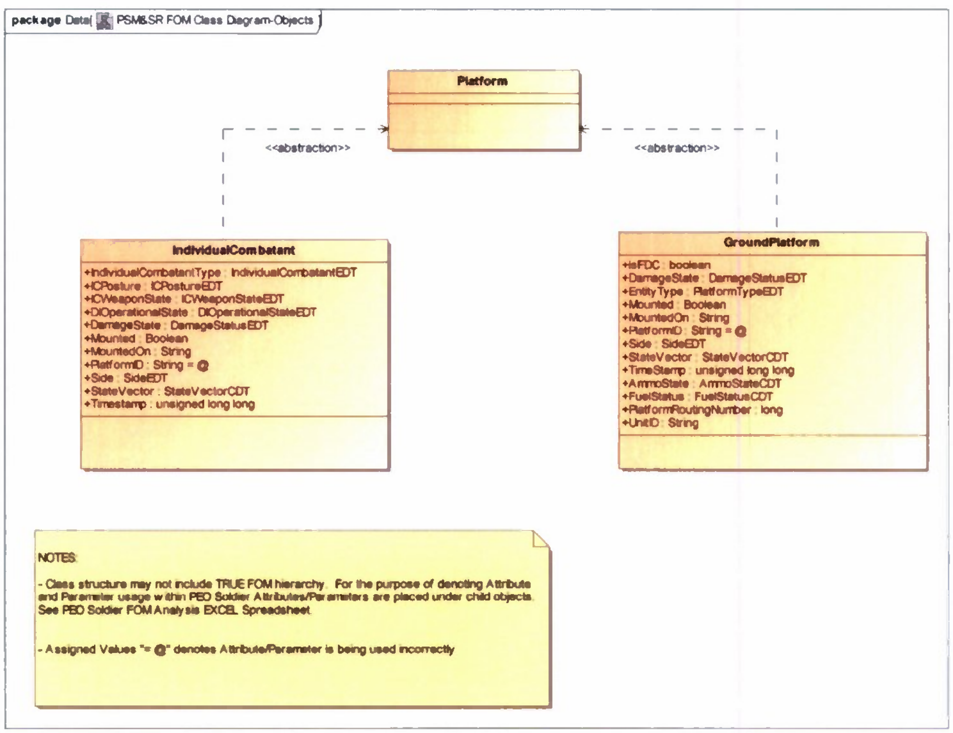

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Fig. 7: PEO Soldier FOM class diagram.

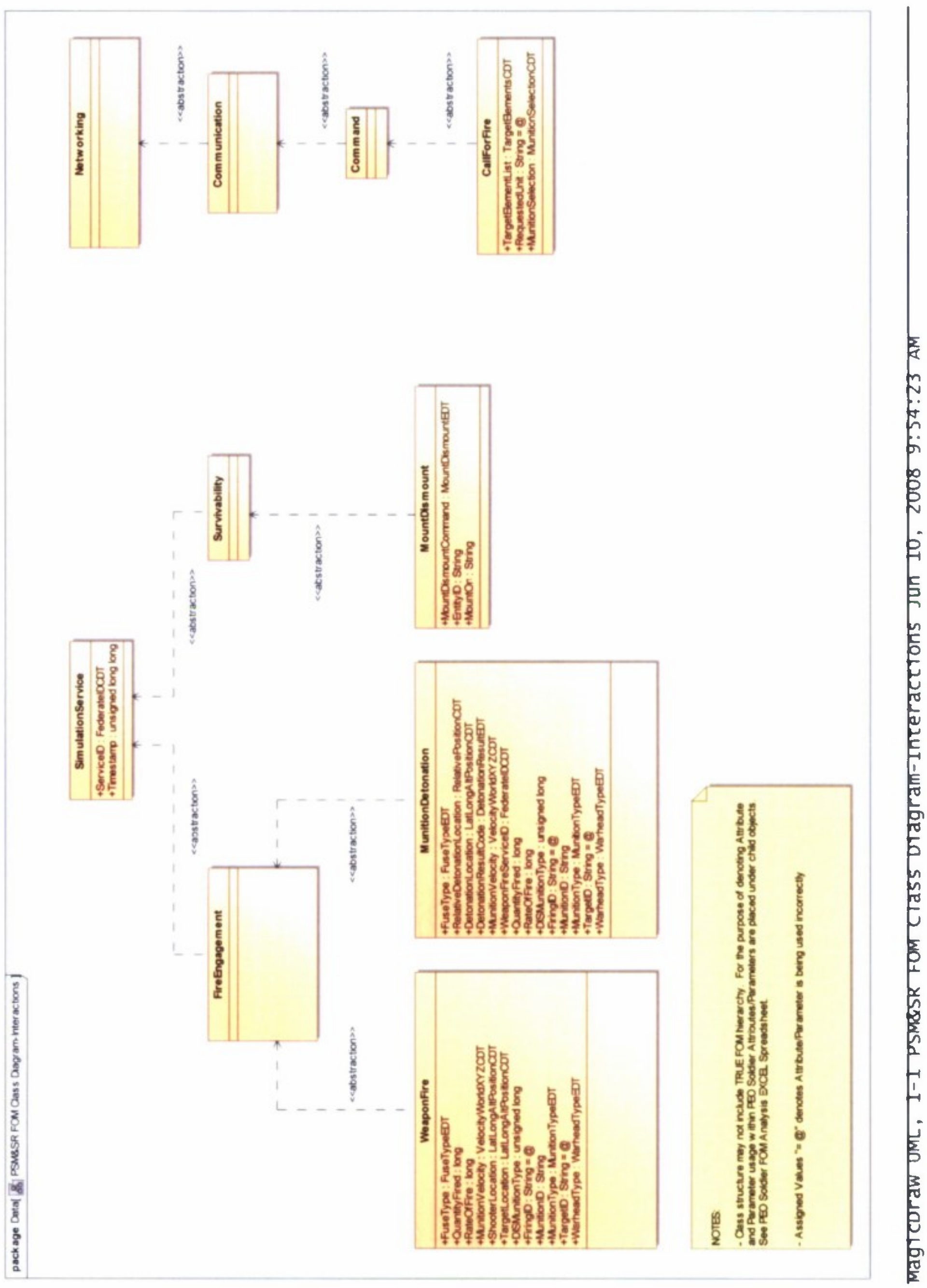

Fig. 8: PEO Soldier FOM interaction diagram.

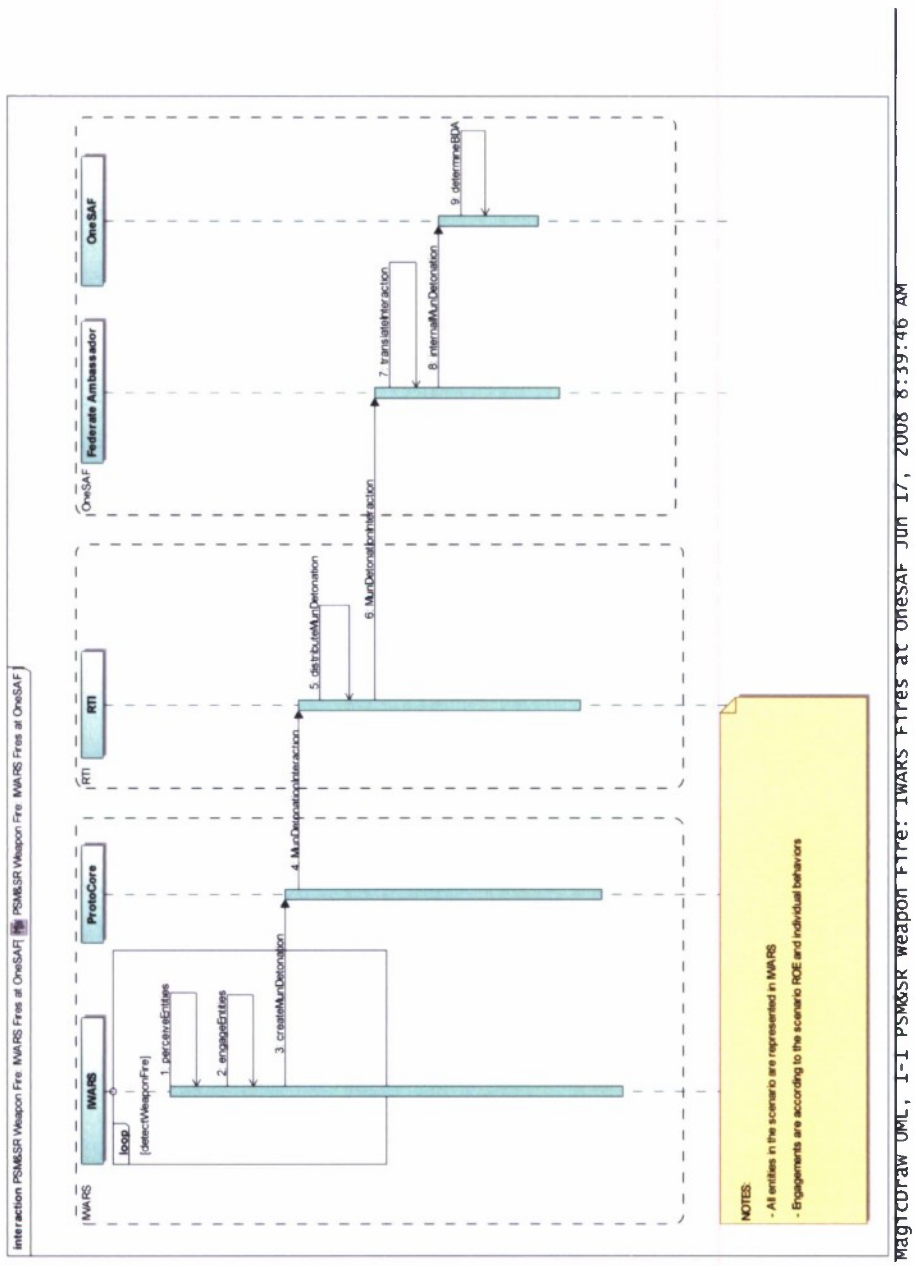

Fig. 9: Sequence diagram for IWARS direct fire at a OneSAF entity.

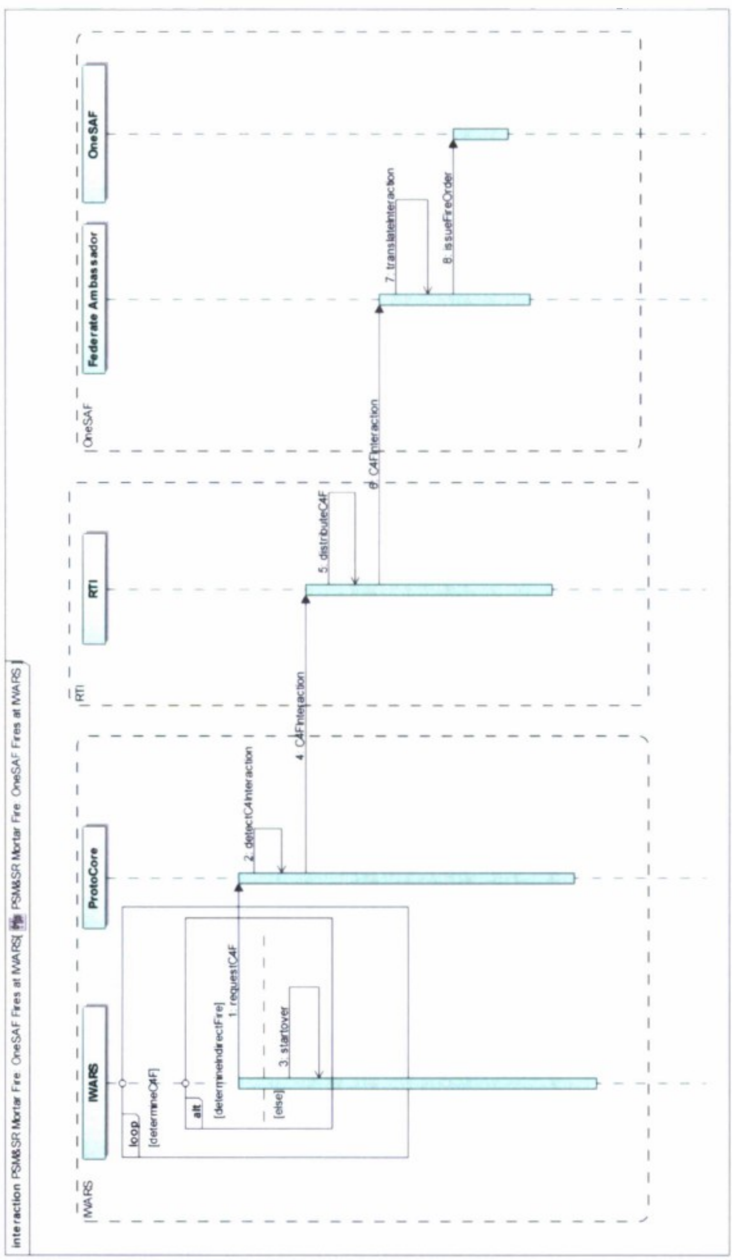

Fig. 10: Sequence diagram for OneSAF mortar fire at IWARS target.

3 Results

Using the architecture described in the previous section, the development team came together for an integration exercise to test the capabilities of the federation. The scenario was designed not necessarily for doctrinal correctness, but to serve as a good test for the models. It needed to be simple to execute, but it also needed to provide the right level of interactions between the two models. Figure 11 shows the initial scenario screens for both OneSAF and IWARS. The scenario called for a squad of infantry to mount in two HMMWV's in order to move into a small town to raid a house.

As the HMMWV's approach the town, enemy lookouts are spotted on the roof of a home, and the friendly forces call for fire. The enemy forces and dismounted observer are represented in IWARS, and the mortars are represented in OneSAF. Once the call for fire is executed, the rounds impact in and around the building, incapacitating the enemy lookouts as shown in Figure 3. These interactions, represented in the sequence diagram of Figure 10, test the ability of IWARS to pass call for fire information to IWARS and the ability of OneSAF to engage forces represented in IWARS with indirect fire.

Once the enemy lookouts on the roof are cleared, the HMMWV's stop at a dismount point, and the members of the squad dismount the vehicles in order to infiltrate on foot to the raid target. As the squad dismounts, their control is passed from OneSAF to IWARS, shown in Figure 13.

The dismount squad breaks into two teams, and one moves into a support by fire position while the other moves toward the raid objective. The HMMWV's remain in an overwatch position blocking one of the roads out of the town. At this time, two armed insurgents come to the rooftop of the raid objective and fire at the approaching squad. They are spotted and engaged by the HMMWV's, as shown in Figure 14. This sequence of events demonstrates the ability of the insurgents, controlled by IWARS, to have a direct fire engagement with the HMMWV's, controlled by OneSAF. The sequence diagram in Figure 9 represents information exchanges for these interactions.

As the insurgents on the rooftop are incapacitated, the raid team moves to the objective and clears the house of remaining insurgents, as shown in Figure 15. This activity takes place only in IWARS.

The scenario concludes, and relevant performance measures can be collected from IWARS results, OneSAF results, or from data collected from the network during the federated run.

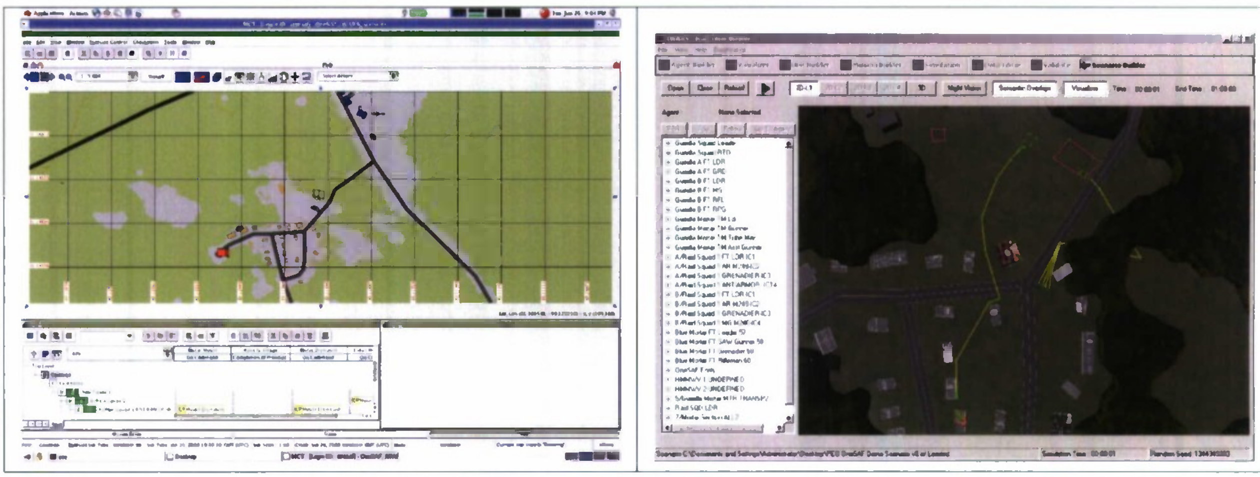

Fig. 11: Scenario startup screenshots for OneSAF (left) and IWARS (right)

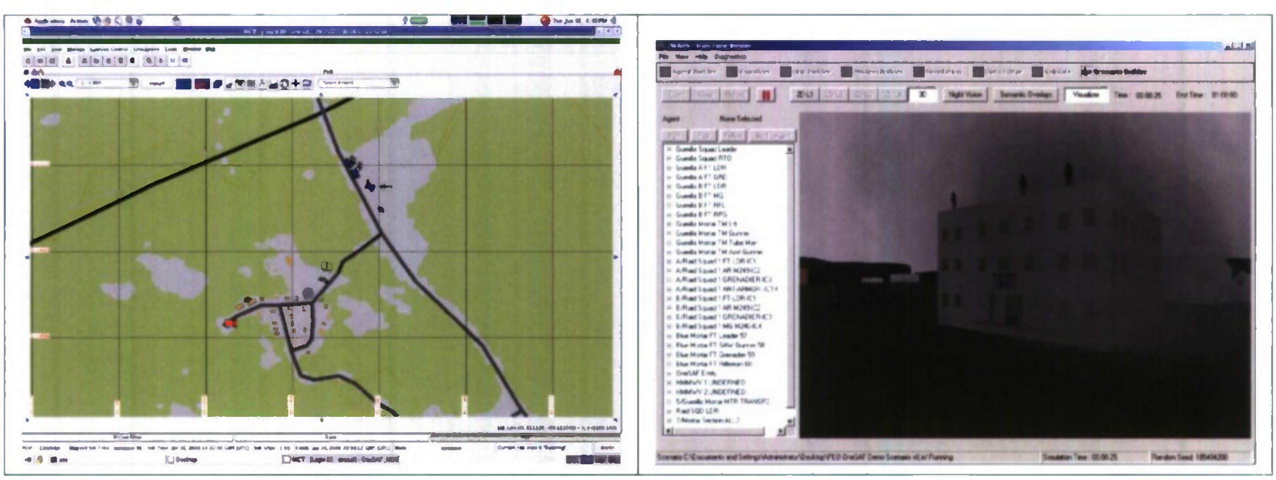

Fig. 12: Enemy lookouts on a rooftop are engaged by mortars in OneSAF (left), and the effects on the dismounted enemy forces are seen in IWARS (right).

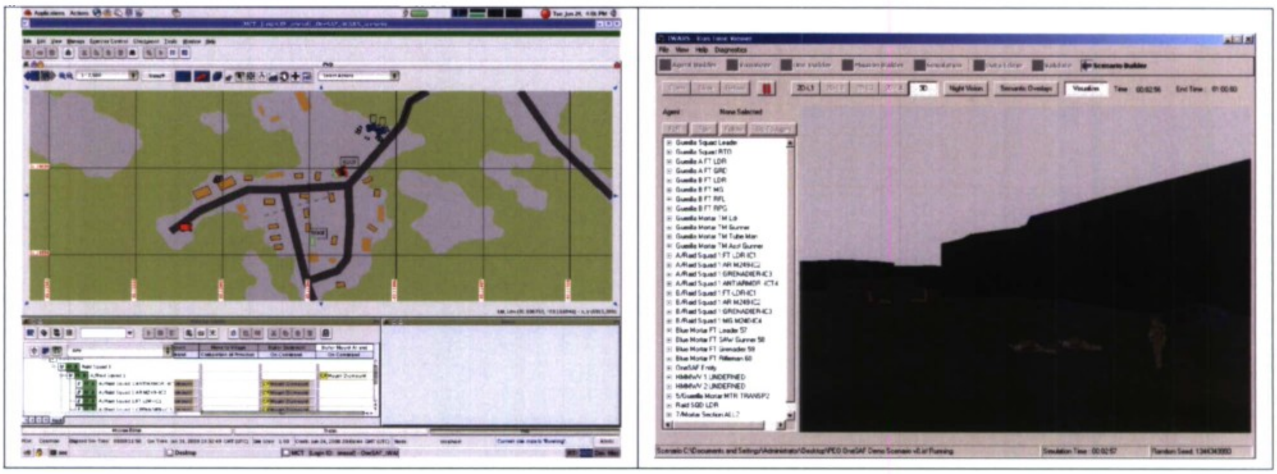

Fig. 13: As the HMMWV's stop in OneSAF (left), the raid squad dismounts, and their control is passed to IWARS (right).

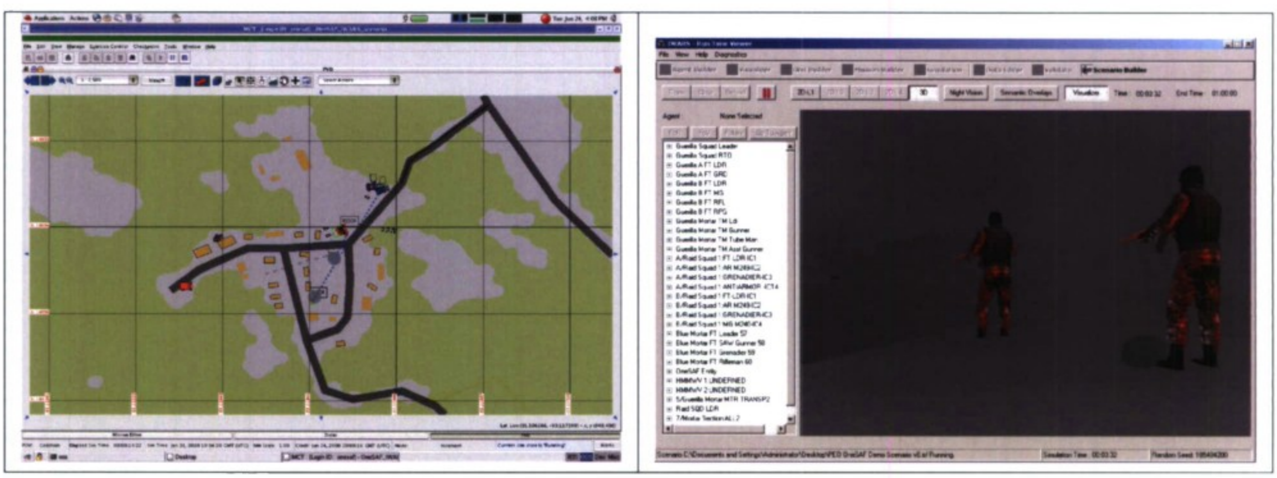

Fig. 14: HMMWV's in OneSAF (left), fire at insurgents controlled by IWARS (right).

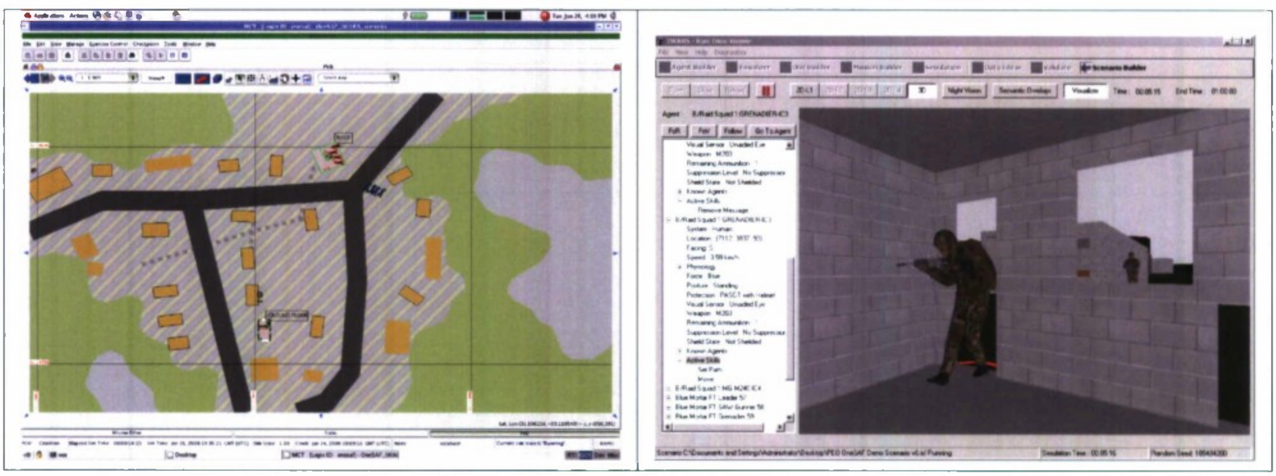

Fig. 15: OneSAF (left) shows the results of the room clearing activity which takes place in IWARS (right).

4 Planning for Academic Year 2008-2009 Work

This year's effort gives a capability for movements, target acquisitions, and firing effects to be exchanged between the models. While this progress is significant, much more work needs to be done before this federation is ready for analysis of complex soldier equipment such as the Ground Soldier System, a dismounted command and control capability. Soldier communications, situation awareness, and command and control decisions must be represented. In addition, the federation must be able to support automatic start and stop, time management, and data collection for analysis. Finally, even thought the individual models have been verified and validated, the federation itself must be verified, validated, and accredited for use in an Army study.

4.1 Simulation Architecture

In order to support these modeling tasks, an updated federation architecture must be developed. A high-level view of this architecture is shown in Figure 16. Within this architecture, IWARS is expected to perform high resolution simulation of soldiers on the battlefield. Specific components from the MATREX architecture will provide battle command capabilities. MATREX provides a group of federates in the Battle Command Management Services (BCMS). The Message Transceiver Service (MTS) provides an interface to a communications models such as the Communications Effects Server. In the upcoming year, this project will attempt to identify an appropriate communications effects federate to model soldier communications. This federate will by linked with the MATREX architecture via the MTS, which provides HLA interfaces for communications messages. In addition the Situation Awareness Dissemination Service (SANDS) will correlate and fuse situation awareness for soldier leaders on the battlefield at the team, squad, and platoon level. The Soldier C2 Model will be developed at West Point in order to read situation awareness data from SANDS and order subordinates to change mission parameters based on this awareness. This Soldier C2 model will be aware of the friendly situation, mission, enemy situation, and terrain. Its decision algorithms will provide better decisions when presented with more complete and more accurate situation awareness information that would be presented via soldier communications systems such as the Land Warrior System or Ground Soldier System. OneSAF or COMBAT^{XXI}will simulate the effects of mounted forces or higher-level units on the battlefield with which soldiers operate.

4.2 Tasks

From the planned architecture shown in Figure 16, a list of development tasks was prepared for each model development team to carry forward into the upcoming development year (See Annex B). These tasks were staffed to each development team for review and costing. Based on the feedback, PEO Soldier provided sufficient funds to each team in order to continue development in accordance with the planned architecture, using the assigned tasks. These tasks were integrated into an overall project plan for academic year 2008-2009, shown in Annex C.

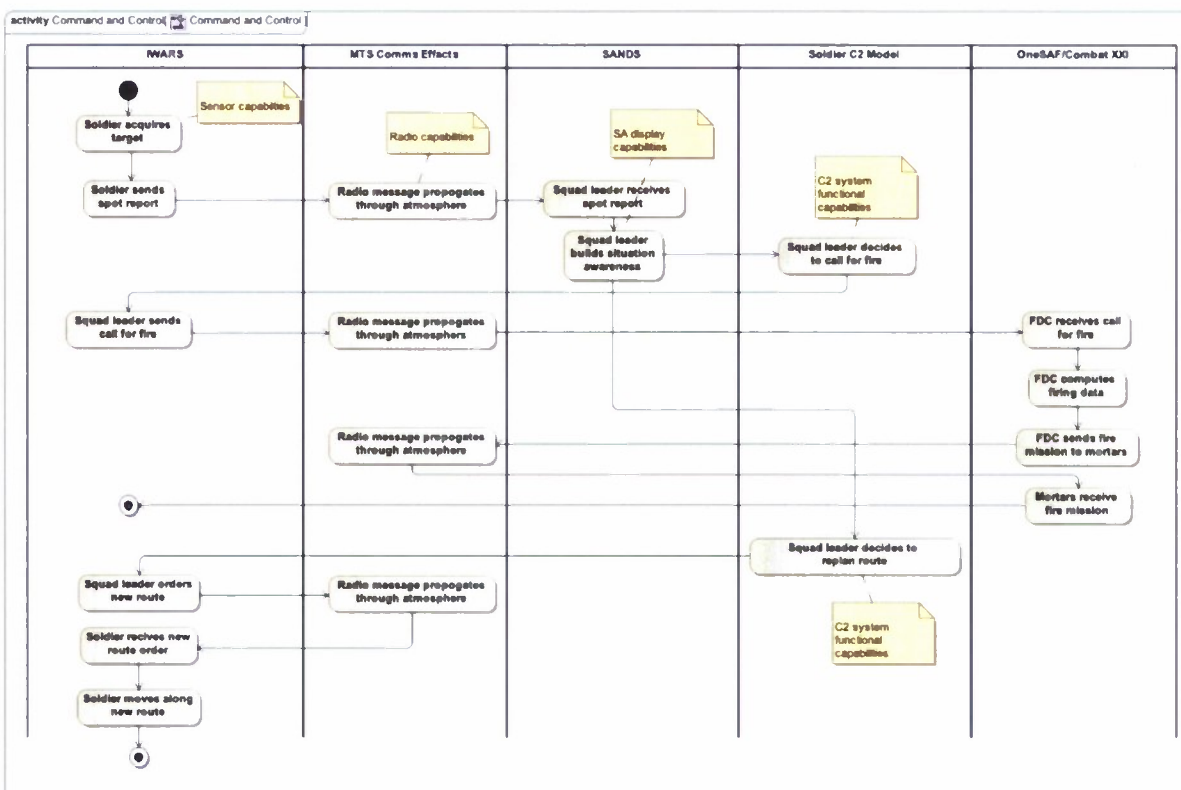

Fig. 16: Planned simulation architecture for assessment of command and control systems.

References

Army Modeling and Simulation Office (2002, September). *Planning Guidelines for Simulation and Modeling for Acquisition, Requirements, and Training, Change 1.* Army Modeling and Simulation Office.

Board, I.-S. S. (2000a). IEEE standard for modeling and simulation (M&S) high level architecture (HLA) - object model template (OMT) specification. Technical Report IEEE 1516.2-2000, IEEE-SA Standards Board.

Board, I.-S. S. (2000b). IEEE standard for modeling and simulation (M&S) high-level architecture (HLA) federate interface specification. Technical Report IEEE 1516.1-2000, IEEE-SA Standards Board.

Boylan, G. L. (2006, June). PEO Soldier simulation roadmap: Continued efforts in implementation. Technical Report DTIC ADA448073, United States Military Academy Operations Research Center, West Point, NY.

Hurt, T., T. McKelvey, and J. McDonnell (2006). The modeling architecture for technology, research, and experimentation. In L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto (Eds.), *Proceedings of the 2006 Winter Simulation Conference*, pp. 1261–1265.

IEEE Computer Society (2003). IEEE Recommended Practice for High Level Architecture (HLA) Federation Development and Execution Process (FEDEP). Technical Report 1516.3.

IEEE-SA Standards Board (2000, September). IEEE standard for modeling and simulation (M&S) high level architecture (HLA) - framework and rules. Technical Report IEEE 1516-2000.

Kramlich, G. (2007). PEO Soldier simulation roadmap III: Initial working federation. Technical Report DSE-TR-0704, United States Military Academy Operations Research Center, West Point, NY.

Martin, G. (2005, July). PEO Soldier simulation roadmap: Initial steps in implemetation. Technical Report DTIC ADA435707, United States Military Academy Operations Research Center, West Point, NY.

Object Management Group (2002). Meta Object Facility specification. Technical Report Version 1.4, Object Management Group.

Object Management Group (2003a). MDA guide version 1.0.1. Technical report, Object Management Group.

Object Management Group (2003b). XMI version 1 production of XML schema specification. Technical Report Version 1.3, Object Management Group.

Object Management Group (2007). OMG model driven architecture. http://www.omg.org/mda. accessed 14 march 2008.

Sheehan, J. H., P. H. Dietz, B. E. Bray, B. A. Harris, and A. B. Wong (2004). The military missions and means framework. Technical Report TR-756, Army Material Systems Analysis Activity.

Tolk, A., C. D. Turnitsa, S. Y. Diallo, and L. S. Winters (2006). Composable M&S web services for netcentric applications. *Jornal of Defense Modeling and Simulation 3*(1), 27–44.

Tollefson, E. S. and G. L. Boylan (2004, September). Simulation roadmap for program simulation roadmap for Program Executive Office (PEO) Soldier. Technical Report DTIC ADA425648, United States Military Academy Operations Research Center, West Point, NY.

Nomenclature

BCMS Battle Command Management Services

C-BML Coalition Battle Management Language

C2 Command and Control

COMBAT^{XXI} Combined-Arms Analysis Tool for the 21st Century

DIS Distributed Interactive Simulation

FEDEP Federation Development and Execution Process

HLA High Level Architecture

IWARS Infantry Warrior Simulation

MATREX Modeling Architecture for Technology Research and Experimentation

MATREX Modeling Architecture for Technology, Research, and Experimentation

MDA Model Driven Architectures

MMF Military Missions and Means Framework

MOF Meta-Object Facility

MSDL Military Scenario Definition Language

MTS Message Transciever Service

NATO North Atlantic Treaty Organization

OMT Object Model Template

OneSAF One Semi-Automated Forces

ORCEN Operations Research Center of Excellence

PEO Program Executive Office

RDECOM Research Development and Engineering Command

RTI Run Time Interface

RTI Runtime Interface

SANDS Situation Awareness Dissemination Service

SEDEP Synthetic Environment Development and Exploitation Process

SISO Simulation Interoperability Standards Organization

SMART Simulation and Modeling for Acquisition Requirements and Training

STMS Soldier Tactical Mission System

TENA Test and Training Enabling Architecture

UML Unified Modeling Language

USMA United States Military Academy

VMASC Virginia Modeling Analysis and Simulation Center

XMI XML Metadata Interchange

XML Extensible Markup Language

ANNEX A - Development Tasks for Academic Year 2007-2008

Tab. 3: COMBAT XXI Modeling Tasks

Title	Description	Remarks
Real Time Interoperability	Develop hard-linkages between COMBATXXI and IWARS.	Current Work Program will not allow us to begin hard-linkages prior to Dec 07. Objective is to model platoon MOUT objective in IWARS and then transfer to COMBATXXI for follow on.
Combat XXI ERC	Integrate ERC into COMBATXXI.	ERC proponent must provide ERC with a Java interface for this to be accomplished.
Attend TEM's	Attend Technical Exchange Meetings	Until Dec 07, meetings should occur at TRAC-WSMR when possible, or by VTC.
SWA 100 Scenario	Provide SWA 100 COMBATXXI Scenario.	Provided when complete and tested.
Combat XXI MSDL Schema	Implement MSDL schema into scenario input/output into COMBATXXI	Current Work Program will not allow us to begin integration of MSDL schema prior to Dec 07. Spring SIM publishes draft MSDL in March. Final schema published at Fall SIM.
Academic year 2008-2008 COMBAT^{XXI} modeling tasks		

Tab. 4: IWARS Modeling Tasks

Title	Description	Remarks
Thermal Weapons Sight Improvements	Develop, in conjunction with AMSAA, the trade-off performance parameters, associated with 10%, 25%, 50% and 100% capability improvements (resolution) for the Thermal Weapon Site; and create data tables to integrate these inputs into the IWARS model to support analysis within the context of a Southwest Asia operational use case.	Most likely needs detail classified information from PM-SWAR. We would also want to get some the data from NVESD studies pertaining to classification of hand-held items.
IWARS MSDL Schema	Implement MSDL schema into scenario input/output into Infantry Warrior Simulation	Spring SIM publishes draft MSDL in March. Final schema published at Fall SIM.
Academic year 2008-2008 IWARS modeling tasks		

Tab. 4: IWARS Modeling Tasks

Title	Description	Remarks
IWARS Thermal Weapons Sight Scenario	Create IWARS scenario to analyze the effects of Thermal Weapon Site within high density urban environment in a desert environment, typical of operations within Southwest Asia, during both day and limited visibility scenario.	Operational use case would be that of a SE Asia desert location. Objective end state would be to have a level of compatibility with, or take a slice of the TRAC HRS 100 or 110. An urban canyon that is roughly 300 meters in depth to test rifle and optic effects to this distance may be part of the use case. To ensure a common terrain representation with the other simulations for the area of interest, we would be dependent upon others to provide the specific terrain database(s).
Entity level sensory and behavior algorithms for TWS	Develop the entity level simulation sensory and behavior algorithms associated with enhanced Thermal Weapon Site capabilities within the context of a Southwest Asia operational use case.	Related to IWARS-01 and IWARS-03
Thermal Weapons Sight Analysis	Conduct an analysis using the products from steps 1, 3, & 4. Provide results to PEO-Soldier and USMA.	There are numerous steps in this process, many of which are called out in a previously provided narrative. Would want numerous interactions with PEO-Soldier and USMA during execution.
Real time interoperability	Continue to address necessary linkage elements in conjunction with the OneSAF and COMBATXXI groups, working towards a hard linkage with each COMBAT XXI and OneSAF individually.	Linkage elements will either focus on elements compatible with TRAC-WSMR scenarios being worked during this period, near-term analysis needs of PEO-Soldier or on representing FFW and GSS within the context of FCS to facilitate simulation based analysis, training, experimentation or testing. Specific elements supporting hard linkage have been previously identified. The major issues that would have to be addressed are different with OneSAF and CXXI, i.e. method of exchanging data. Form of delivery will need to be discussed.
Academic year 2008-2008 IWARS modeling tasks		

Tab. 4: IWARS Modeling Tasks

Title	Description	Remarks
IWARS Communications	Work with the OneSAF and COMBATXXI (Lead) groups in addressing the analytical needs associated with communications and their effects. There are two main issues, the first being the representation of 'Communications Equipment' and the second includes the representations of actions that can be taken based upon having the information from the communications, i.e. "Netted Effects: Call for Fire". 31DEC07 The solutions to integrating these capabilities in the models are different. The first requires that parameters associated with the communications equipment have an impact upon the success of the communication. The second requires that behaviors are developed and utilized that allow the computer entities to take actions (fires) based upon the information passed in the communication.	The solutions to integrating these capabilities in the models are different. The first requires that parameters associated with the communications equipment have an impact upon the success of the communication. The second requires that behaviors are developed and utilized that allow the computer entities to take actions (fires) based upon the information passed in the communication.
Long-term Issues	"Work with PEO Soldier and other agencies, as required and as opportunities arise to address long-term issues of interest to the PEO. A number of specific areas have been explicitly identified. – Analytical needs associated with Soldier borne power and energy. – Analytical needs associated with the 'Direct Fire Weapons' area of endeavor. – Benefits of an "Integrated Vision / Aim Point System" on lethality. – Analytical needs associated with the "Blue Soldier Tracking Alerts" area of endeavor – Analytical needs associated with the Interceptor Body Armor; integrated head, neck, and face protection; and Advanced Combat Helmet areas of endeavor. – The need to work to obtain a minimum-spanning set of operational use cases that will support materiel development, analysis and experimentation. – The set-up, conduct, and reduction of experiments that support the collection of data needed for analysis – The set-up, conduct, and reduction of analysis pertaining to issues of importance to the PEO Soldier.	
Academic year 2008-2008 IWARS modeling tasks		

Tab. 5: OneSAF Modeling Tasks

Title	Description	Remarks
OneSAF Casualty Modeling	Development of capabilities/affects for advanced body armor and the Thermal Weapon Site and integration of the Integrated Casualty Estimation Model (ICEM). This includes conceptual modeling, KA/KE, model implementation, integration, and test	
Command and Control Items	Work with the IWARS and COMBATXXI groups in addressing the needs and benefits associated with the "Netted Effects: Call for Fire," "Integrated Vision/Aim Point System," "Blue Soldier Tracking Alerts," "Direct Fire Weapons," and "Communications Equipment" area of endeavors.	
OneSAF MSDL	Implement MSDL schema into scenario input/output into OneSAF	Spring SIM publishes draft MSDL in March. Final schema published at Fall SIM.
ERC	As the primary effort for this year, serve as the "Lead" to activities pertaining to facilitating the integration of the OneSAF Environmental Runtime Component (ERC) into Combat XXI and IWARS. Collaborate with the other two modeling groups to ensure that efforts are aligned and mutually supportive to enable ERC utilization of the COMBAT XXI scenario SWA 100	Terrain decks may be classified, and if necessary, require a SIPR Line
Academic year 2008-2008 OneSAF modeling tasks		

ANNEX B - Planned Development Tasks for Academic Year 2008-2009

Task	Assigned To	Description	Remarks
Continued HLA Federation Development	Combat XXI	Work with other modeling teams to continue HLA development toward a more robust representation of communications, command and control, lethality, and protection.	Specific tasks include: Build MATREX communications support Build MATREX fires architecture support Build MATREX situation awareness support Build behavioral responses to MATREX Soldier C2 interactions.
Assess federation analysis capabilities	Combat XXI	Use a small scenario to assess the federation's capability to assess the operational value of different soldier architectures including the current soldier system, Land Warrior, and Ground Soldier System.	Specific tasks include: Update interface to Protocore 4.1 Update support for ERC and MSDL 2.5 Support automatic federation start/stop Support time management Support entity ownership transfer Document SOM in OMT Develop data collection capabilities to support analysis.
Communications Modeling	Combat XXI	Develop a capability for IWARS to run as a stand-alone communications effects model.	This communications model must work in a MATREX architecture by integrating with the MATREX Message Transceiver Service (MTS). It will receive messages from MTS and use the Brigade and Below Propagation and Protocol (B2P2) model to determine whether message passed from sender to receiver.
Develop PEO Soldier Scenarios	Combat XXI	From currently approved TRADOC scenarios work with USMA and PEO to extract small scale analysis vignettes from within those scenarios. These vignettes should address recurring PEO Soldier analysis questions.	Deliverables will be MSDL representations of these scenarios for use by all of the subordinate models. Assignment of this task is intended to leverage the soldier analysis expertise of TRAC-WSMR.
Soldier Modeling Team	Combat XXI	Participate in two annual soldier modeling team conferences to discuss common concerns with respect to development processes, behaviors, algorithms, and data.	

Fig. 17: COMBAT^{XXI}tasks for academic year 2008-2009.

Task	Assigned To	Description	Remarks
Continued HLA Federation Development	IWARS	Work with other modeling teams to continue HLA development toward a more robust representation of communications, command and control, lethality, and protection.	Specific tasks include: Build MATREX communications support Build MATREX fires architecture support Build MATREX situation awareness support Build behavioral responses to MATREX Soldier C2 interactions.
Integrated Casualty Estimation Model	IWARS	Develop a methodology and data requirements for the use of ICEM results in combat simulations.	AMSAA cooperation is required for this task. Run-time issues prevent real-time linkage with ICEM.
Rules of Engagement	IWARS	Develop representations and soldier behaviors that capture the effects of IFF systems and rules of engagement in combat simulations.	The fidelity of these representations depends on progress in the underlying science from across the R&D community.
Assess federation analysis capabilities	IWARS	Use a small scenario to assess the federation's capability to assess the operational value of different soldier architectures including the current soldier system, Land Warrior, and Ground Soldier System.	Specific tasks include: Update interface to Protocore 4.1 Update support for ERC and MSDL 2.5 Support automatic federation start/stop Support time management Support entity ownership transfer Document SOM in OMT Develop data collection capabilities to support analysis.
Improve STA process for soldier sensors	IWARS	Improve representation of soldier sensors and the search and target acquisition process within combat simulations.	Where appropriate, implement existing methodologies in IWARS.

Fig. 18: IWARS development tasks for academic year 2008-2009

Task	Assigned To	Description	Remarks
Continued HLA Federation Development	OneSAF	Work with other modeling teams to continue HLA development toward a more robust representation of communications, command and control, lethality, and protection.	Specific tasks include: Build MATREX communications support Build MATREX fires architecture support Build MATREX situation awareness support Build behavioral responses to MATREX Soldier C2 interactions.
Assess federation analysis capabilities	OneSAF	Use a small scenario to assess the federation's capability to assess the operational value of different soldier architectures including the current soldier system, Land Warrior, and Ground Soldier System.	Specific tasks include: Update interface to Protocore 4.1 Update support for ERC and MSDL 2.5 Support automatic federation start/stop Support time management Support entity ownership transfer Document SOM in OMT Develop data collection capabilities to support analysis.
Soldier Modeling Team	OneSAF	Participate in two annual soldier modeling team conferences to discuss common concerns with respect to development processes, behaviors, algorithms, and data.	
Assess Federation Analysis Capabilities	PEO Soldier	Use a small scenario to assess the federation's capability to assess the operational value of different soldier architectures including the current soldier system, Land Warrior, and Ground Soldier System.	Specific tasks include detailed descriptions of different soldier as a system architectures. Provide analysis questions that currently answer PEO Soldier decision challenges with respect to these architectures.
Map soldier capability gaps to modeling requirements	PEO Soldier	PEO Soldier should identify and prioritize the soldier capability gaps they are addressing. They will then work with the Simulation Road Map team to map those gaps to simulation requirements so that simulation resources can be directed at the issues of concern for the PEO.	

Fig. 19: OneSAF and PEO soldier tasks for academic year 2008-2009

Task	Assigned To	Description	Remarks
Assess Federation Analysis Capabilities	USMA	Use a small scenario to assess the federation's capability to assess the operational value of different soldier architectures including the current soldier system, Land Warrior, and Ground Soldier System.	Specific tasks include orchestrating input data development across the models, conducting the analysis runs, collecting and analyzing output data, answering the study question, and providing feedback about model development priorities that would enhance the analysis capabilities of the federation.
Command and Control Modeling	USMA	Build an ability for reactive command and control into the federation. These behaviors must be friendly, enemy, and terrain aware.	First effort will be to identify soldier C2 behaviors at individual, fire team, squad, and platoon level. Then develop C2 interactions to be used in the FOM to pass these behaviors into the models. Once each model has built internal responses to these C2 behaviors, develop C2 federates that pass orders to soldier entities based on updated C2 information about friendly forces, enemy forces, mission, and terrain.
MDA for Federation Development	VMASC	Continue to assess the applicability of Model Driven Architectures to the federation development process.	For this year, place particular emphasis on the further development of the MATREX/PROTOTCORE environment in order to use a systems engineering approach to move from requirements, to system selection, to orchestration, and execution.
Battle Management Language for Soldier C2	VMASC	Support development of soldier C2 architecture with Battle Management Language (BML) representations of soldier C2 tasks.	Support includes data definition for BML structures and prototype implementation of command and control federates that assess the current situation and issue orders to soldiers using BML.
Assess federation analysis capabilities	VMASC	Use a small scenario to assess the federation's capability to assess the operational value of different soldier architectures including the current soldier system, Land Warrior, and Ground Soldier System.	Specific VMASC task will be to focus on the federation's handling of data for analysis. How does the analyst configure the federation to collect the appropriate data to support the analysis questions given the different data collection instruments on the federation and within the individual models.
Federation development engineering management plan	VMASC	Develop an engineering management plan to support the federation development tasks planned for academic year 2008-2009. Support execution of that plan with assessments of on-time and performance criteria during execution.	Delivery of the plan would take place toward the end of the summer to support planning for next year's effort.

Fig. 20: USMA and VMASC tasks for academic year 2008-2009

ANNEX C - Project Plan for Academic Year 2008-2009

ID	Task Name	Duration	Start	Finish	Predecessors	6/1
1	**PEO Soldier Simulation Road Map**	**480 days?**	**Mon 6/16/08**	**Fri 4/16/10**		
2	**Roll AY2008 Changes into baseline releases**	**81 days?**	**Mon 6/16/08**	**Mon 10/6/08**		
3	**IWARS Modeling**	**71 days**	**Mon 6/16/08**	**Mon 9/22/08**		
4	Roll AY2008 Modeling into IWARS 1.5	1 mon	Mon 6/16/08	Fri 7/11/08		
5	Update IWARS to use Protocore 4.1 with associated FOM	2 wks	Mon 7/14/08	Fri 7/25/08	4	
6	Update IWARS to use ERC 2.5 (Version that ships with OneSAF 2.5)	2 wks	Tue 9/9/08	Mon 9/22/08	11	
7	Update IWARS to use MSDL 2.5 (Version that ships with OneSAF 2.5)	2 wks	Tue 9/9/08	Mon 9/22/08	12	
8	**OneSAF Modeling**	**70 days?**	**Mon 6/16/08**	**Fri 9/19/08**		
9	Roll AY2008 Modeling into OneSAF 2.5	3 mons	Mon 6/16/08	Fri 9/5/08		
10	Update OneSAF to use MATREX FOM 4.1	2 wks	Mon 9/8/08	Fri 9/19/08	9	
11	Release ERC 2.5	1 day?	Mon 9/8/08	Mon 9/8/08	9	
12	Release MSDL 2.5	1 day?	Mon 9/8/08	Mon 9/8/08	9	
13	**Combat XXI Modeling**	**81 days**	**Mon 6/16/08**	**Mon 10/6/08**		
14	Replicate AY2008 Modeling in Combat XXI	3 mons	Mon 6/16/08	Fri 9/5/08		
15	Update Combat XXI to use Protocore 4.1 with associated FOM	2 wks	Mon 9/8/08	Fri 9/19/08	14	
16	Update Combat XXI to use ERC 2.5 (Version that ships with OneSAF 2.5)	1 mon	Tue 9/9/08	Mon 10/6/08	11	
17	Update Combat XXI to use MSDL 2.5 (Version that ship with OneSAF 2.5)	1 mon	Tue 9/9/08	Mon 10/6/08	12	
18	**Federation Analysis and Technical Capabilities**	**50 days**	**Mon 7/28/08**	**Fri 10/3/08**		
19	**IWARS Modeling**	**10 days**	**Mon 7/28/08**	**Fri 8/8/08**		
20	IWARS Automatic Federation Start/Stop Capability	2 wks	Mon 7/28/08	Fri 8/8/08	5	
21	IWARS Time mangement to allow faster than real time run sets	2 wks	Mon 7/28/08	Fri 8/8/08	5	
22	IWARS Passing of entity ownership	2 wks	Mon 7/28/08	Fri 8/8/08	5	
23	Document IWARS internal SOM in OMT	2 wks	Mon 7/28/08	Fri 8/8/08	5	
24	**OneSAF Modeling**	**10 days**	**Mon 9/22/08**	**Fri 10/3/08**		
25	OneSAF Automatic Federation Start/Stop Capability	2 wks	Mon 9/22/08	Fri 10/3/08	10	
26	OneSAF Time mangement to allow faster than real time run sets	2 wks	Mon 9/22/08	Fri 10/3/08	10	
27	OneSAF Passing of entity ownership	2 wks	Mon 9/22/08	Fri 10/3/08	10	
28	Document OneSAF internal SOM in OMT	2 wks	Mon 9/22/08	Fri 10/3/08	10	
29	**Combat XXI Modeling**	**10 days**	**Mon 9/22/08**	**Fri 10/3/08**		
30	CombatXXI Automatic Federation Start/Stop Capability	2 wks	Mon 9/22/08	Fri 10/3/08	15	
31	CombatXXI Time mangement to allow faster than real time run sets	2 wks	Mon 9/22/08	Fri 10/3/08	15	
32	CombatXXI Passing of entity ownership	2 wks	Mon 9/22/08	Fri 10/3/08	15	

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Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

ID	Task Name	Duration	Start	Finish	Predecessors	6/1
33	Document CombatXXI internal SOM in OMT	2 wks	Mon 9/22/08	Fri 10/3/08	15	
34	Federation Test Event 1 (Test AY2008 scenario updated to Protocore 4.1 and latest models)	1 wk	Mon 10/6/08	Fri 10/10/08	29,24,19	
35	**Systems Engineering**	**115 days**	**Mon 6/16/08**	**Fri 11/21/08**		
36	identify soldier systems under consideration for FY10 and FY11	1 mon	Mon 6/16/08	Fri 7/11/08		
37	Identify soldier missions and tasks effected by soldier systems under consideration	1 mon	Mon 7/14/08	Fri 8/8/08	36	
38	Develop Analysis Scenario	1 mon	Mon 8/11/08	Fri 9/5/08	37	
39	Identify how to measure capabilities increases and decreases in analysis scenario	1 wk	Mon 9/8/08	Fri 9/12/08	38	
40	Capture missions and means in analysis scenario in UML	2 wks	Mon 9/15/08	Fri 9/26/08	39	
41	Allocate functional capbilities to federates	2 wks	Mon 9/29/08	Fri 10/10/08	40	
42	Design federation in Protocore tools to support requirements	1 mon	Mon 10/13/08	Fri 11/7/08	41	
43	Generate code stubs to enable federate integration	1 wk	Mon 11/10/08	Fri 11/14/08	42	
44	Generate test cases to enable federation integration	1 wk	Mon 11/17/08	Fri 11/21/08	43	
45	**Command and Controi Modeling**	**200 days**	**Mon 6/16/08**	**Fri 3/20/09**		
46	**Soidier Communications Modeling**	**125 days**	**Mon 6/16/08**	**Fri 12/5/08**		
47	Gain understanding of MTS and its use in MATREX	1 mon	Mon 6/16/08	Fri 7/11/08		
48	Identify appropriate communications effects model analysis of soldier communications	2 mons	Mon 7/14/08	Fri 9/5/08	47	
49	Integrate commincations model with MTS	2 mons	Mon 9/8/08	Fri 10/31/08	48	
50	Build communications test case	1 wk	Mon 11/3/08	Fri 11/7/08	49	
51	**Buiid MATREX communications support into federates**	**20 days**	**Mon 11/3/08**	**Fri 11/28/08**	**34,49**	
52	Build MATREX communictions support into IWARS	1 mon	Mon 11/3/08	Fri 11/28/08		
53	Build MATREX communictions support into OneSAF	1 mon	Mon 11/3/08	Fri 11/28/08		
54	Buiid MATREX communictions support into CombatXXI	1 mon	Mon 11/3/08	Fri 11/28/08		
55	Test communicatons functionality using communications test scenario	1 wk	Mon 12/1/08	Fri 12/5/08	52,53,54,49,50	
56	**Modeiing of the Fires Process**	**75 days**	**Mon 8/11/08**	**Fri 11/21/08**		
57	Identify functional tasks supporting fires process and capture in UML	1 mon	Mon 8/11/08	Fri 9/5/08	37	
58	Allocate fires functional capabilities to federates	1 mon	Mon 9/8/08	Fri 10/3/08	57	
59	Build fires test scenario	2 wks	Mon 10/6/08	Fri 10/17/08	58	
60	**Buiid MATREX fires support into federates**	**20 days**	**Mon 10/20/08**	**Fri 11/14/08**	**59,34**	
61	Build MATREX fires support into IWARS	1 mon	Mon 10/20/08	Fri 11/14/08		
62	Build MATREX fires support into OneSAF	1 mon	Mon 10/20/08	Fri 11/14/08		
63	Build MATREX fires support into CombatXXi	1 mon	Mon 10/20/08	Fri 11/14/08		
64	Test fires functionality using firest test scenario	1 wk	Mon 11/17/08	Fri 11/21/08	60	

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Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

ID		Task Name	Duration	Start	Finish	Predecessors	6/1
65		**Situation Awareness Modeling**	**115 days**	**Mon 6/16/08**	**Fri 11/21/08**		
66		Gain an understanding of C3 Grid and its use in MATREX	2 mons	Mon 6/16/08	Fri 8/8/08		
67		Identify functional tasks supporting situation awareness and capture in UML	1 mon	Mon 8/11/08	Fri 9/5/08	37	
68		Allocate situation awareness functional capabilities to federates	1 mon	Mon 9/8/08	Fri 10/3/08	67	
69		Build SA test scenario	2 wks	Mon 10/6/08	Fri 10/17/08	68	
70		**Build MATREX SA support Into federates**	**20 days**	**Mon 10/20/08**	**Fri 11/14/08**	**69,34**	
71		Build MATREX SA support into IWARS	1 mon	Mon 10/20/08	Fri 11/14/08		
72		Build MATREX SA support into OneSAF	1 mon	Mon 10/20/08	Fri 11/14/08		
73		Build MATREX SA support into CombatXXI	1 mon	Mon 10/20/08	Fri 11/14/08		
74		Capture and model soldier SA in C3 Grid	1 mon	Mon 10/20/08	Fri 11/14/08		
75		Test SA functionality using firest test scenario	1 wk	Mon 11/17/08	Fri 11/21/08	70	
76		Federation test event 2 (Show communications, fires, and SA functionality using AY2008 sce	1 wk	Mon 12/8/08	Fri 12/12/08	46,56,65	
77		**Command and Control Decision Modeling**	**120 days**	**Mon 9/29/08**	**Fri 3/13/09**		
78		Identify functional tasks supporting C2 and capture in UML	1 mon	Mon 9/29/08	Fri 10/24/08	40	
79		Allocate C2 functional capabilities to federates	1 mon	Mon 10/27/08	Fri 11/21/08	78	
80		Build C2 data structures for inclusion in MATREX FOM	1 mon	Mon 11/24/08	Fri 12/19/08	79	
81		Extend MATREX FOM to support soldier C2 data structures	1 wk	Mon 12/22/08	Fri 12/26/08	80	
82		Build C2 test scenario	2 wks	Mon 12/29/08	Fri 1/9/09	81	
83		**Build MATREX C2 support into federates**	**40 days**	**Mon 1/12/09**	**Fri 3/6/09**	**82**	
84		Build MATREX C2 support into IWARS	1 mon	Mon 1/12/09	Fri 2/6/09		
85		Build MATREX C2 support into OneSAF	1 mon	Mon 1/12/09	Fri 2/6/09		
86		Build MATREX C2 support into CombatXXI	1 mon	Mon 1/12/09	Fri 2/6/09		
87		Develop C2 federate to make appropriate C2 decisions	2 mons	Mon 1/12/09	Fri 3/6/09		
88		Test C2 functionality using firest test scenario	1 wk	Mon 3/9/09	Fri 3/13/09	83	
89		Federation test event 2 (Show C2 functionality using th AY2009 scenario)	1 wk	Mon 3/16/09	Fri 3/20/09	77	
90		ICEM Casualty Modeling Capability	8 mons	Mon 6/16/08	Fri 1/23/09		
91		IFF and Rules of Engagement Modeling	8 mons	Mon 6/16/08	Fri 1/23/09		
92		Improve STA Process for Soldier Sensors	8 mons	Mon 6/16/08	Fri 1/23/09		
93		Model Soldier Power Consumption	8 mons	Mon 6/16/08	Fri 1/23/09		
94		Build federation data collection capability	8 mons	Mon 6/16/08	Fri 1/23/09		
95		Conduct analysis using the developed federation	2 mons	Mon 3/23/09	Fri 5/15/09	91,92,93,94,89,76	
96		Verify and validate the federation	12 mons	Mon 5/18/09	Fri 4/16/10	95	

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Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The purpose of this study is to continue to build a capability for PEO Soldier to assess the platoon level effectiveness of different soldier equipment architectures using distributed simulation. Three combat models - IWARS, OneSAF, and COMBAT XXI - are integrated via the High-Level Architecture (HLA) in order to provide this capability. This year's effort focused on developing and demonstrating a runtime interaction between IWARS and OneSAF. In addition, a systems engineering methodology is proposed and demonstrated for driving federated simulation development with operational requirements. This methodology relies heavily upon the Military Missions and Means Framework, the Federation Development and Execution Process, and Model Driven Architectures. Successful integration was achieved with a squad-level scenario, and continued development will refine this federation by joining COMBAT XXI, adding analysis capabilities, and preparing for verification and validation.

15. SUBJECT TERMS

Distributed Simulation, High Level Architecture, Combat Modeling, Model Driven Architectures, Systems Engineering

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