JOEF (Joint Operational Effects Federation) Architecture

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ABSTRACT: *JOEF (Joint Operational Effects Federation) is a simulation federation that supports CBRN (Chemical Biological Radiological and Nuclear warfare on military operations. Its primary interface to users is JWARN (Joint Warning and Reporting Network), which is an automated reporting of CBRN incidents for the joint or each service. It also automates the transfer of data between CBRN detectors/sensors and C4I systems, and minimizes the effects of a hostile attack, accidents or incidents.*

Therefore, the fundamental role of JOEF is to provide the modeling and simulation analytical capability to determine and assess the impact of CBRN warfare on military operations. It specifically supports assessment of wartime operations and risk levels, assessment of wartime preparations for employment of CBRN defenses and resources, and advance planning and analysis to support assessment of CBRN operational alternatives in conjunction with JWARN in real-time mode.

This paper describes the JOEF conceptual architecture for the structure of operational-effects models (i.e., transport and dispersion models). The architecture includes the specification of software module interfaces so that the modules become plug-and-play operational effect simulations. It also allows for direct interfaces to a web-based application and user interfaces. Finally, the architecture is compliant to DII-COE, which is the DOD C4I interface standard.

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1 Introduction

Recently, the importance of Nuclear, Biological and Chemical (NBC) defense and responses to such an attack has been significantly escalated. Due to the nature of the NBC materials, a real usage of them for either training, mission planning, concept development, or acquisition-related testing and trade off studies should be minimized as much as possible. Simulation approach is an answer.

However, existing DoD Modeling and Simulation (M&S) systems do not include an accredited, complete representation of the full operational-battlespace environment. While pieces of the capability may exist in some battlefield simulations, existing capabilities do not support or contain a full set of operational requirements modeling and simulation (ORMS) capabilities required to support Chemical Biological Radiological Nuclear (CBRN) defense requirements. Further, efforts conducted outside the Chemical, Biological (CB) defense program have not addressed these issues and consequently do not possess the critical CBRN defense characteristics that will be required of the JOEF.

Current CBRN effects models and simulations are emerging from the technology development community and are designed to improve warfighting skills and to develop the concepts and capabilities required to effectively operate in the contaminated environment. A continuous identification,

development, production, and fielding of accredited CBRN effects models and simulations is critical to maintaining the simulated environment necessary for sustaining a fighting force. As such, CBRN operational effects modeling and simulation capabilities are high priority requirements detailed in the Joint Future Operational Capabilities (JFOCs) priority listing.

That is, joint forces have the immediate need to safely operate, survive and sustain operations in an NBC threat environment. It should be noted that NBC Battle Management, Commanders at all levels must [1, 2]:

- Quickly and effectively quantify the risks associated with various courses of action
- Provide a real-time portrayal of the current status of NBC effects/impacts on the Battlespace
- Provide timely information through early and direct warning.

The current preliminary assessment of modeling and simulation (M&S) capability to determine and assess the impact of NBC agents on military operations are lacking following areas:

- No realistic capability exists within DoD to assess the impact of NBC attacks on critical fixed site or mobile forces operations
- NBC weapon effects models do not impart any information of the agents impact on a unit's ability to carry out its wartime mission
- Current systems are not user friendly and do not provide the required analytical sophistication.

Consequently, a new simulation system has to be built to meet the above critical requirements without building all necessary components from scratch. The new system has to fully satisfy all the requirement of commanders at all levels and related supporting tasks such as training, rehearsal, mission planning, acquisition, testing, concept/TTP (Tactics Techniques and Procedures) developments, and acquisition supports. JOEF (Joint Operational Effects Federation) is, thus, introduced.

2 JOEF (Joint Operational Federation Effects Federation) Overview

JOEF Objective

The overall objective of JOEF is to provide a modeling and simulation (M&S) analytical capability to assess the impact of CBRN warfare on military operations. As such this includes such sub-objectives as:

- Analyze operational issues and doctrine through the interrelation and effects of various elements within the overall system
- Assess the performance of particular equipment based on deployment of sensors, CBRN resources, and medical resources.
- Assess an individual warfighter, and groups of warfighter ability to perform joint mission essential tasks.
- Assess the impact on military operations of an individual warfighter's ability to perform mission essential tasks under CBRN conditions.
- Assess the impact of CBRN threats and providing risk levels and estimate levels of impacts (causalities, sortie generation.)

Having the ability to integrate with, make use of, and/or be federated with transport, dispersion, and hazard information systems and models for NBC hazard prediction and real-time data. As stated previously, JOEF is conceived to be an operational requirements modeling and simulation tool to enable warfighters, commanders, war planners, and the acquisition community to:

- Determine CBD operational effectiveness
- Provide a tool for the future development of CBD operational requirements
- Provide a tool to evaluate tactics, techniques and procedures (TTPs), doctrine, and CONOPS development
- Provide a tool to evaluate new technology and concepts
- Provide a tool to evaluate training and contingency planning
- Provide a tool to rehearse plans.

JOEF Roles

The fundamental role of JOEF is to support the warfighter and his commander to assess the impact of chemical, biological, radiological and nuclear (CBRN) warfare on military operations. In the near term, JOEF will support wartime operations, and deliberate planning and analysis, and in the long term a near real time decision-making functionality. This long-term capability centers on providing computer-aided decision support tools to assist warfighter and commanders in assessing and mitigating CBRN warfare operational degradation and vulnerabilities during real world operations. A diagram depicting JOEF block 1's potential role in Joint War-games is shown in Figure 1.

Another role for JOEF is to be a M&S tool to support the DOD and Service acquisition communities in the

assessment of CBRN defensive system alternatives when conducting analyses of alternatives or investigating virtual prototypes. In addition, the Services will use the JOEF as a M&S tool in support of existing CBRN programs.

JOEF Operational View

JOEF is a set of models, simulations, tools, and equipment interfacing and performing transactions required by the decision makers and analysts in performing their duties and responsibilities in CBRN battle management. Figure 2 illustrates operational view of JOEF. JOEF is conceived to be an operational requirements modeling and simulation tool to enable warfighters, war planners, and the acquisition community to:

- Determine CBRN operational effectiveness
- Support the future development of CBRN operational requirements
- Support tactics, techniques and procedures (TTPs), doctrine, and CONOPS development
- Support technology and concept evaluation
- Support training and contingency planning
- Support non-real time analysis, and deliberate planning
- Support near-real time situation assessment and decision making.

JOEF federates with other DoD M&S applications using validated models of military forces that predict how forces will perform in the Battlespace. Further, JOEF accesses certified databases used across the Chemical Biological (CB) commodity areas and DoD, and JOEF supports system acquisition decision making in Joint Service CBRN programs by being the analytic tool for identifying key performance parameters and critical acquisition system characteristics.

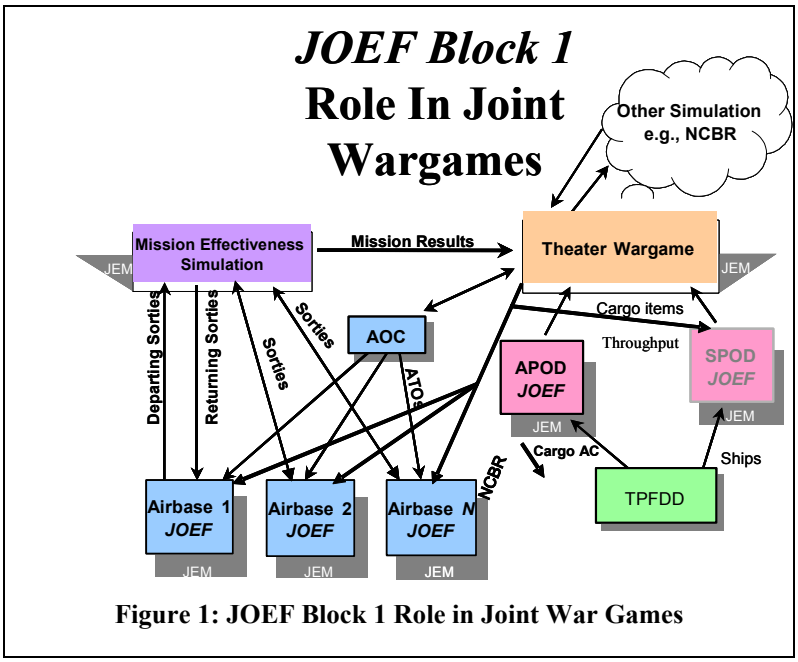

Figure 1: JOEF Block 1 Role in Joint War Games

JOEF Block Development

JOEF will be developed via the concept of blocks or increments of functional performance. The use of this process will make it possible to add user priority capabilities in a timely manner tailored to program budgetary constraints. The planned block developments are:

Block 1: This first phase will provide an accredited tool designed to replace and/or augment manual and computer-based systems and processes currently used by the Services to evaluate CBRN warfare operability at "high threat" air bases and aerial ports of debarkation (APODs). Block 1 will streamline the analytic requirements process and provide initial tools and data analysis to support CBRN defense operational requirements modeling and simulation, and will address both fixed site and medical requirements. This fixed site operability model will:

- Be used as the core for user defined input parameters
- Provide a modeling and simulation analysis capability for assessing "high threat" air base operability and APODs. The output of these will be centered on assessment of the CB defense effectiveness and its impact on sortie generation and cargo throughput respectively.
- Provide the basic algorithms that will allow assessment of impact and risk in the four commodity areas.
- Initial integration with DOD combat simulation using the High Level Architecture (HLA) or equivalent.
- Initial Defense Information Infrastructure Common Operating Environment (DII-COE) compliance (level 5).
- Provide a tool for the development of training materials.
- Provide a tool for the evaluation of existing and new requirements.

Block 2: Further expansion of the scope of JOEF to include seaports of debarkation (SPODs) and other land-based fixed site targets (i.e., depots). Cargo throughput and manpower/hardware consideration trade-offs will be included. This block will provide the output links to theater and campaign level models.

Block 3: Expansion of the scope of JOEF to include mobile land and littoral forces. This block provides output links into manpower, logistics and training planning models.

Block 4: This block of development will address the near real time decision support requirements of war-fighting JOEF users. JOEF will refine its basic algorithms to provide near real time assistance to warfighters, commanders, and CBRN mission analysis to help them assess and mitigate operational degradation and vulnerabilities during real world operations. This block of JOEF will provide the user with the ability to quickly examine multiple options and make near real-time mission effectiveness comparisons (impact and risk estimations). This block will achieve full C4I system integration.

Figure 2: JOEF's Continuous Improvements Role in Battle Management

3 JOEF Capabilities

In operational and strategic planning analysis JOEF shall have the capability to generate requirements baselines, performance characteristics, operational effectiveness, and vulnerability based on measures of effectiveness (MOE) based on threat and concept of operations combinations:

Contamination Avoidance Effectiveness: JOEF provides contamination avoidance measures by providing configurable scenarios for NBC detectors with specific performance levels for detectors and NBC recognizance units, and the associated warning and reporting network. It is these resources that provide the means for avoiding the contaminated areas. The parameterization of the detectors includes agent classes, agent types, minimum and maximum concentration detection levels, and the quantification performance. These parameters are programmable or selectable in order to show impact of specific requirements. JOEF will calculate contamination avoidance effectiveness by normalizing the generic operational impact of the contamination avoidance resources with the operation impact that occurs without any contamination avoidance resources.

Collective Protection Effectiveness: JOEF provides collective protection measures of effectiveness by providing configurable scenarios of collective protection resource. This includes collective protection facilities, medical hospitals, over pressure protection for mobile ground (vehicles), ships, and fixed site buildings or vehicles. It is these resources that provide the means for collective protection. JOEF collective protection effectiveness measure includes the analyzes of the Time-Phased Force and Deployment Data (TPFDD) populations, existing shelters, the unhardened and hardened facilities, and the planned deployment of Harvest Falcon/Harvest Eagle system sets (tents, messing facilities, etc.). TPFDD data must be integrated into collective protection systems to determine force structure and sustainment requirements. JOEF will calculate collective protection effectiveness by normalizing the generic operational impact of the collective protection resources with the operation impact that occurs without any collective protection resources.

Individual protection: Provide baselines (including degradation) for CBRN respiratory and below the neck protection of personnel in all modes of operational and tactical/non-tactical environments. Support analyzing maneuver and fixed site threats and performance profiles required to support each mission, including special operations forces (SOF). Protective parameters of protective masks, respirators, and ensembles must be selectable in order to show operational impact of theater specific requirements.

Decontamination/Restoration: Provide baselines for CBRN decontamination systems and decontaminants to support decontamination and restoration of personnel, equipment, vehicles (aircraft, ground, and ships) and fixed sites. The capabilities of decontaminants and their properties (toxicity, disposal,

etc.) must be selectable in order to show operational impact of specific material requirements.

4 JOEF Technical Approach

JOEF's technical approach will be to:

1) Evaluate the time based three dimensional concentration contours of a CBRN attack based on the nature of the attack and environmental conditions;
2) Model operational awareness of the threat provided by sensors, sensor networks, and human reports;
3) Integrate the time concentration for a track or locations (fixed facility, mobile unit, mobile vehicle, and individuals, or groups of individuals.) to calculate the dosage exposure;
4) Modulate the concentrations with attenuation factors, such as the concentration reduction due to operation procedures, contamination avoidance, individual protection, collective protection, and decontamination, to calculate the dosage resulting from the concentration modulation,
5) JOEF will then use the dosage estimates to provide levels of impact on the fixed facilities, mobile units, mobile vehicles, and individuals. The impact will be computed by using a line time integration of the concentration along the position locus of the facilities, units, vehicles, and individuals, etc.
6) With evaluations for each location or track, JOEF will generate time contours of impact and risk. Impact will be measured in terms of the percentage of personnel with the effects of various dosage hazard levels {none; low (Protect eyes from Symptoms: Miosis, Conjunctivitis, Rhinorrhea, and Tightness in Chest); medium (Mask required – Protect lungs); High (Suit required– Protect Skin)}. Risk will be measured based upon impact due to dosage hazard level, and probability of occurrence. JOEF will use the standard DoD risk assessment definitions to make risk assignments of none, low, medium and high. The impact will be calculated by using a line time integration of the concentration along the position locus of the facilities, units, vehicles, and individuals, etc.
7) JOEF will then use the time contours of impact to estimate the measures of effectiveness for the operations within the facility including responsive action to maintain operations in the presence of CBRN and defensive action, by normalizing the impact by the normal operating effectiveness.
8) Thus JOEF will satisfy its general requirement by modeling the CBRN performance characteristics of the warfighting systems with user-defined simulation scenarios. Data generated during simulation execution will be post-processed to extract the measures of effectiveness and measures of performance for presentation.

JOEF will be also capable of:

- Storing, modifying, retrieving, displaying, and transferring data on requirements analysis and studies. The approach to accomplishing this will be to capture JOEF outputs generated by studies and analyses in a form that can be edited by users with external text editing software.
- Having access to and providing detailed practical information about the characteristics of CBRN systems and other data required for risk assessments. The approach to accomplishing this will be to provide interfaces that will allow JOEF users to access standard CBRN system databases.
- Provide for automated input of critical data, such as terrain data, weather, population database from other systems such as JEM (Joint Effects Model), and JSIMS (Joint Simulation System). The purpose of this requirement is to facilitate JOEF operation that is consistent with the modeling representations of these simulation systems.
- Not causing interference with any host system functions or capabilities during operations. The approach to satisfying this requirement will be to adopt DII COE interoperability standards for C4I system interfaces, and community standards for non-DII COE system interfaces.
- Being upgraded at the Direct Support level and organizational/unit level via on-line download capability for upgrades to system software based upon changes in doctrinal procedure. The approach to satisfying this requirement will be to support distribution of software patches and entire software modules as well as database updates and new databases by internet at appropriate level of security and with appropriate security safeguards.

Each distribution will include user documentation and installation instructions.

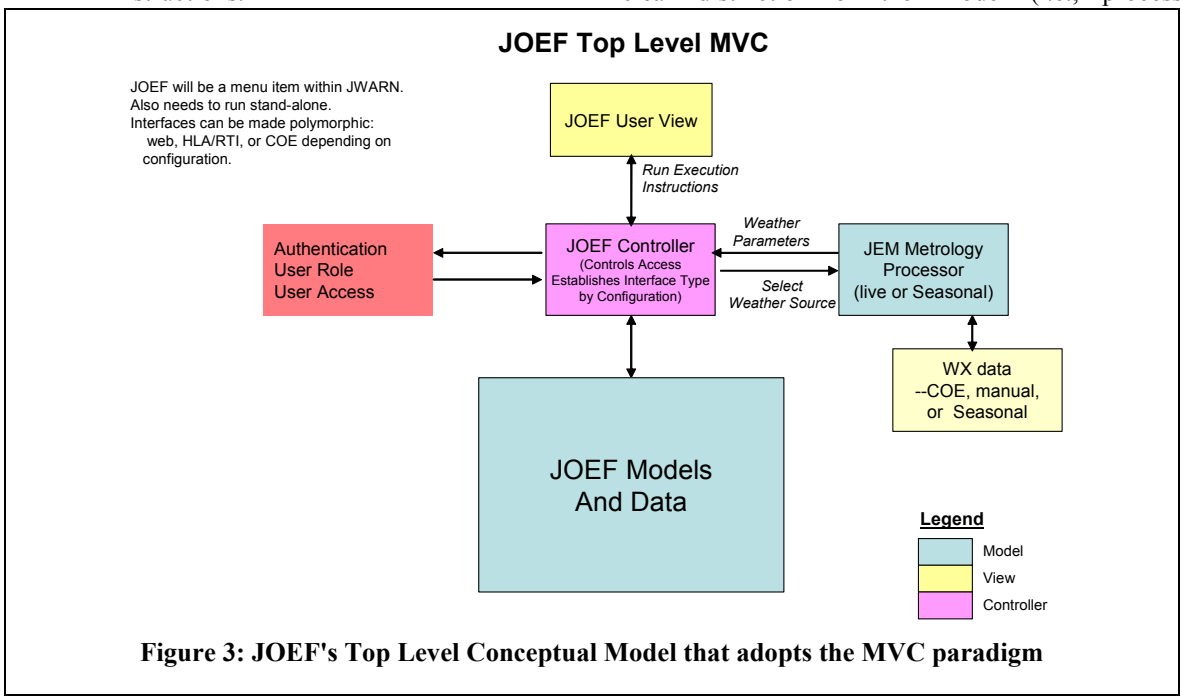

Figure 3: JOEF's Top Level Conceptual Model that adopts the MVC paradigm

5 JOEF Architecture

JOEF architecture [3] explicitly adopts the MVC (Model View Controller) paradigm to take full advantage of the proven design pattern in many important products such as Macintosh GUI/Operating systems, Java Beans, etc. The major feature is the clear distinction of the Model (i.e., processing algorithm), View (user/external system interface), and Controller (data and control distribution and scheduling). This approach automatically leads to a true plug and play paradigm. For example, a viewer, such as User GUI, is absolutely isolated from any

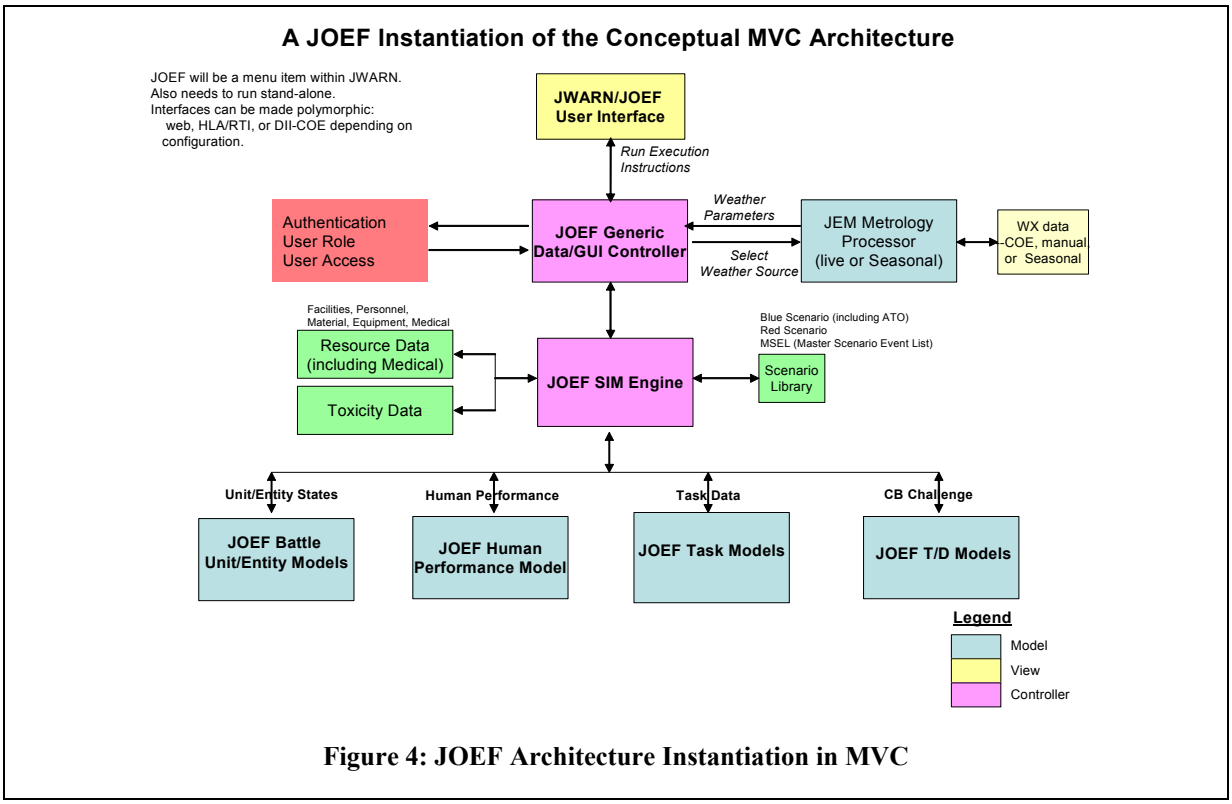

Figure 4: JOEF Architecture Instantiation in MVC

impacts of switching models or underline computing algorithms. To further advance this desirable characteristic, JOEF added one additional constraint on the generic MVC paradigm. In the JOEF, the View will not have direct communication with the Model. The top level JOEF MVC conceptual diagram is constructed as Figure 3. The conceptual MVC architecture is colored with three colors for the model, view, and controller functional blocks. External data inputs/databases are colored with a light green color.

The top level JOEF conceptual model is further refined with the recursive nature of the MVC design pattern. That is, each block is potentially represented with its own MVC pattern. Using the JOEF specific constraint – not to have a direct crosstalk between View and Model to further enhance the plug and play modularity among the functional blocks, the JOEF Conceptual MVC Architecture has been refined to an instantiation of the JOEF Conceptual MVC Architecture as shown the JOEF Conceptual MVC Architecture as shown in Figure 4.

The architecture will enable the Services to use JOEF to cross-utilize information, access databases and exchange data files to support ORMS. This includes analyzing and identifying CBRN defense requirements, performing analysis in support of operations planning, and conducting war gaming and training activities.

JOEF will have the capability to link to existing databases across the CBRN commodity areas. When given initial input of mission parameters and threat, JOEF will provide the analytic foundation for identifying key performance parameters and critical system characteristics.

The architecture shall enable JOEF the capability of storing, modifying, retrieving, displaying, and transferring data on requirements analysis and studies in order for JOEF to provide requirements correlations. JOEF also maximally utilizes the latest technologies to provide a truly plug and play backbone, and a polymorphic interfaces to external worlds. Web and

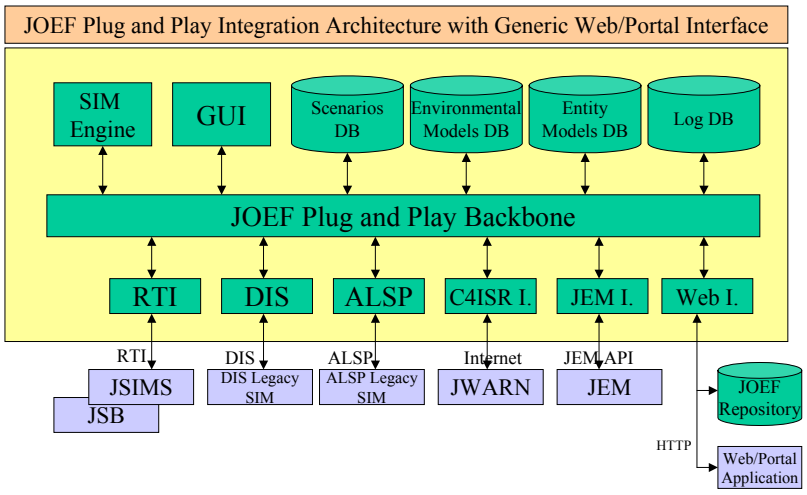

Figure 5: JOEF System Architecture: an Implementation of JOEF Conceptual MVC Architecture

The generic polymorphic interfaces are used to separate the conceptual architecture from an architectural implementation, i.e., JOEF system architecture. The Transport and Dispersion model, Task model, Human effect model become the major components of the JOEF models along with the JOEF Execution/Scheduler module.

JOEF will be federated with other M&S systems, such as JEM, JSIMS and other applicable joint models. It will address fixed sites and medical requirements, with the fixed site operability model used as the core for user defined input parameters.

IT (Information Technology) will be extensively leveraged and integrated into JOEF architecture. The initial JOEF System Architecture is shown in Figure 5.

6 JOEF Interfaces

The Joint Technical Architecture provides DoD systems with the basis for sharing common software and data. The JOEF software, data, operating system, communications, security and user interfaces will be compliant with the JTA, which will provide the foundation for integrating the JOEF with C4ISR systems.

As JOEF is required to accurately depict the CBRN warfare environment including hazard release and subsequent dispersion, sensors and sensor system deployment, as well as the effects of CBRN warfare on personnel, equipment, and operations, it will be necessary to interface with existing M&S applications. HLA is the interface method of choice for linking simulations in dynamically synchronized simultaneous execution, and JOEF is, thus, HLA compliant. Other legacy simulation protocols may be supported as needed. Simple asynchronous data file exchange may be utilized when synchronization is not a requirement. The JOEF Interfaces are depicted in Figure 6.

Since the services will use JOEF to cross-utilize information, access databases and exchange data files to support ORMS, JOEF will have the capability to link to existing databases across the CBRN commodity areas. JOEF will be capable of accessing information from current and planned individual service command, control, communication, and computer (C4) systems, Global Command and Control System (GCCS), DoD Defense Intelligence Information System (DIIS), Defense Information Infrastructure (DII), Common Operating Environment (COE), DMSS, Global Broadcast Service (GBS) Theater Injection Points (TIPs) and the Joint NBC Warning and Reporting Network (JWARN) System. Information and data format must be compatible with the DoD Joint Technical Architecture (JTA). To facilitate interface with these systems, JOEF will comply with Defense Information Infrastructure Common Operating Environment (DII-COE) standards. JOEF will also be able to interface to Internet to allow for interoperations with Web and IT technology based systems.

JOEF will be capable of using collected and modeled CBRN transport, dispersion and hazard information from systems such as JWARN to provide operational decision makers and planners with real and hypothetical CBRN attack data. Connectivity to and interoperability with JWARN is essential to mission accomplishment.

JOEF will use input from JEM modeling and simulation information of CB agent transport, dispersion and hazard information to forecast effects of current real attacks or hypothetical attacks on assigned or future missions to assist in preparation of vulnerability assessments. Connectivity to and interoperability with JEM is essential to mission accomplishment.

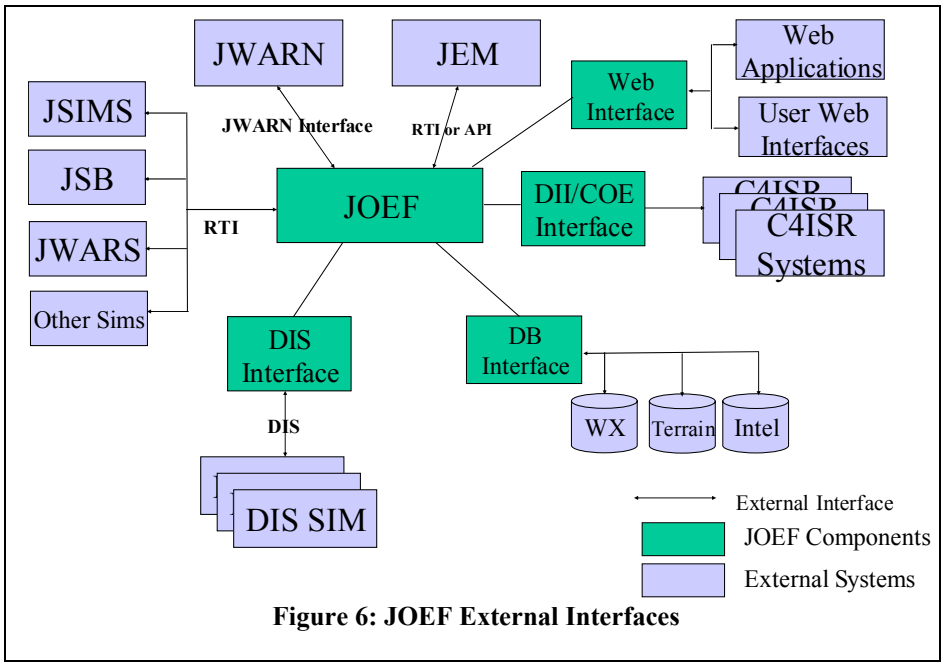

Figure 6: JOEF External Interfaces

JOEF has the capability to provide for automated input of critical data, such as terrain data, weather, population database from other systems such as C4I databases or local user databases. When participating in training events or analysis federations, JOEF will be also able to pull such data from other members of the simulation federation.

JOEF will use the CBRN data standards and guidelines developed by the Joint CB Program to meet the CBRN needs across disciplines and Services. The data must have the capability to interface and interoperate across systems without manual intervention.

C4I systems are moving to web-based applications. Anticipating this trend, JOEF must provide a web interface. One specific web function of JOEF is on-line download capability for upgrades to system software and data. One attractive technology what could allow JOEF to access and translate data is XML. JOEF should use XML as a data interchange technology where appropriate.

Finally, JOEF uses standard DOD Geospatial information products and services directly, to the maximum extent and without intervening transformations. JOEF also complies with World Geodetic System 84 (WGS) and subsequent standards. Further, JOEF will be able to import, use, and export other commercial and government digital Geospatial data as required. The JOEF approach to satisfying this requirement will be to utilize DII COE/GCCS mapping products and NIMA GIS data.

7 Summary and Conclusion

JOEF is a set of models, simulations, tools, and equipment interfacing and performing transactions required by the decision makers and analysts in performing their duties and responsibilities in CBRN battle management by being integrated with JWARN. JOEF also supports acquisition decision related to CBRN detectors/sensors and CBRN related C4I systems. JOEF will be developed via the concept of blocks or increments of functional performance. The four blocks are planned. JOEF is capable of near real-time evaluation of courses of actions under CBRN situations.

JOEF architecture is based on a Model View Controller (MVC) paradigm, and the top conceptual level architecture is recursively refined to include common DOD simulation and JOEF unique components. Then, the conceptual architecture is transformed to JOEF system architecture with a plug and play backbone, which essentially works like a hardware bus in a computer hardware system. Polymorphic external interfaces will be implemented so that external simulation systems and C4ISR systems be easily plugged in JOEF regardless their interface protocols and standards. HLA/RTI, DII/COE and Web interfaces will be also provided through the polymorphic JOEF external interface mechanism.

JOEF is an exemplary usage of simulations, which significantly amplifies the capability of JWARN, an existing C4ISR system. Without JOEF, JWARN is a simple reporting and alert system. However, by being integrated with JOEF, its capability is vastly extended. It will be able to perform a near-real time course of action analysis and a predictive evaluation of CBRN situations. Realistic trainings and mission rehearsals are also possible. To ensure a "mission grade" simulation and prediction capability, the models integrated in JOEF have to be proven and reliable V&V models. JEM (Joint Effects Model) is such a model, and it will compute transport and dispersion of chemical and biological agents in JOEF.

Many of proven Web and IT technologies will be integrated in JOEF to maximize the usage of JOEF to maintain a high level of compatibility of latest computing technologies and to provide a user friendly usage of JOEF.

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