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THE JOINT WARFARE SYSTEM (JWARS): A MODELING AND ANALYSIS TOOL FOR THE DEFENSE DEPARTMENT

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ABSTRACT

Joint Warfare System (JWARS) is a campaign-level model of military operations. User will include the Office of the Secretary of Defense (OSD), the Joint Staff, the Services, and the US Warfighting Commands. Program requirements documents specify implementation that fosters insight into cause and effect relationships encountered by military forces. JWARS will support multi-billion dollar resource allocation decisions and critical operational planning. As a closed-form analytic simulation, JWARS will provide "balanced" representation of joint (modern) warfare. The simulation is mixed-mode, with models that are stochastic or deterministic. The JWARS program will include explicit representation of effects and perturbations caused by information operations on command and control systems in military operations. Relying on state-of-the-art uncertainty modeling concepts, JWARS engineers and domain experts have developed high-level abstractions of sensor and communications systems, the related information flows, imperfect perception of the battlespace, and command decision making.

1 INTRODUCTION

The Joint Warfare System (JWARS) is a campaign-level model of military operations that is currently being developed under contract by the U.S. Office of the Secretary of Defense (OSD) for use by OSD, the Joint Staff, the Services, and the Warfighting Commands. JWARS will provide users with a representation of joint warfare to support operational planning and execution, force assessment studies, systems effectiveness and trade-off analyses, and concept and doctrine development. Intended for analyses, this program will permit studies that require a "balanced representation of Joint Warfare". The simulation's functionality includes: 1) the C4ISR systems and processes that are an integral part of US concept of operations; 2) the impact of logistics, both strategic and intra-theater, in the combat area; and 3) maneuver warfare, at the operational level. These capabilities dispel known deficiencies in the current state-of-the-art in military modeling and form the core modeling contributions of the simulation.

Briefly stated, JWARS is (Maxwell 2000):

- A state-of-the art constructive simulation system using high quality Computer Aided Software Engineering (CASE) tools in a language called IBM VisualAge Smalltalk™. JWARS is an event-stepped simulation that describes the behavior and interaction of military forces across the joint spectrum at a level of resolution previously unachieved at the campaign level. The resulting system models: 1) an explicit three dimensional battlespace, 2) the effects of terrain and weather, 3) logistically-constrained force performance, 4) explicit representation of key information flows, and 5) perception-based command and control.
- A new development that includes unique user involvement for a constructive simulation. Ongoing activities include user's groups, user participation in the design process, and a study team that continuously exercises the simulation. Also, JWARS development is being observed by a formal V&V contractor and is programmed for formal beta and operational testing.
- Under development (currently in Release 1.4 of three major releases). A version for the "early use" familiarization was distributed to eight sites starting in May 2001. To date, many lessons have been learned about simulation software development and combat modeling. JWARS is a complex tool that requires good, comparatively high resolution, data. And, most importantly, it requires a skilled, multidisciplinary team of analysts and military domain experts to formulate, conduct, and interpret simulation experiments and studies.

- Provides analysts an excellent foundation for conducting analyses and research in support of the US Department of Defense (DoD). The tool's limitations reflect the current knowledge boundaries of military modeling and simulation technology. The modeling advances that have been achieved in JWARS have the potential to facilitate meaningful research into emerging doctrinal concepts such as Joint Vision 2020.

The remainder of this paper will describe JWARS design in more detail, emphasizing top-level concepts. Some of the relevant issues and limitations of the simulation will also be presented.

2 JWARS DESIGN AND COMPONENTS

JWARS is an end-to-end (fort-to-port-to-foxhole) constructive simulation of theater and joint military operations at the operational level of war. The behavior of military forces can be simulated from ports of embarkation through to their activities in a warfight. As depicted in Figure 1, JWARS will replace the following systems and their associated functionality.

	Legacy Models	JWARS
Domains	**1 or 2:** Land, Air (Thunder, TACWAR) Sea, Air (ITEM) Air-only (Brawler) Land-only (VIC) Mobility-only (MIDAS)	**8:** Space; Air; Land; Sea; Sub-Surface; Mobility; Logistics; Perception
Domain Interfaces	**1 or 2:** Land-Air (Thunder, TACWAR) Sea-Air (ITEM)	**At least 5:** Land-Air; Sea-Air; Land-Sea; Land-Subsurface Sea-Subsurface (Mine Warfare) Air-Subsurface (USW)
Departments	**Typically 1 represented fully**	**All Fully Represented and Balanced Across Departments**
Command and Control	**Max of 3 Levels of Command**	**5 Levels of Command**
Rule Sets	**Typically Scripted**	**Dynamic Closed-Form C4ISR**

Figure 1: Comparing Legacy Models with JWARS

The JWARS system is composed of three software domains that are integrated into a single executable package that is then used to perform studies and analyses. They are problem, simulation, and platform. The problem domain provides the software that describes the warfighting functionality of analytic interest. The simulation domain provides the "engine" that drives the simulation through time. It also provides the three dimensional battlespace. Conceptually, this battlespace is the Synthetic Natural Environment (SNE) in which the entities exist. The platform domain provides the JWARS hardware, and the Human Computer Interface (HCI) that helps analysts and others get data into and out of the simulation. Figure 2 provides an overview of the development domains.

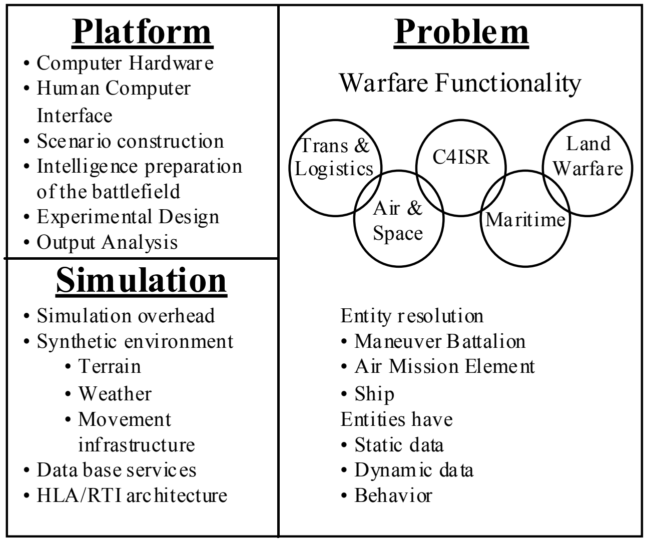

Figure 2: JWARS Domains

2.1 JWARS Problem Domain

The fundamental building block for representing military forces and systems in JWARS is called the Battle Space Entity (BSE). The nominal level of resolution of BSEs is at the battalion level for maneuver units, air mission elements for air operations, ships for maritime assets, and individual platforms for critical ISR systems (*e.g.* JSTARS, U2s). There are also "special case" BSEs such as: ports, airfields, key headquarters units (*e.g.* division headquarters), and chemical clouds. BSEs contain data that represent both static and dynamic properties. Static data represent values that do not change, such as a unit's authorized strength, or the range of a missile system. Dynamic data (*e.g.* unit strength, location) can change over time. The data also point to behaviors that enable BSE interactions with each other and the environment. All BSEs have some organic command and control capability. The complexity of the C2 varies depending on the BSEs characteristics. Figure 3 portrays the key components of a Battle Space Entity.

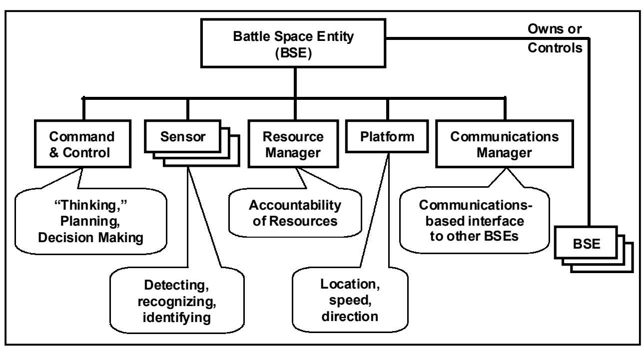

Figure 3: Battle Space Entity Components

A JWARS scenario contains a set of BSEs for all the forces that are to be played. The scenario also includes plans that the BSEs will execute as part of their missions and tasks. One extremely important contribution of JWARS is that it simulates the activity of forces before the war starts. The current JWARS scenarios begin many days before any combat occurs, simulating the movement of units from their original duty station into the theater. Operationally, this part of the campaign is called "the road to war". Historically these conditions have not been modeled, but were treated in campaign level analyses as a set of assumptions (based on off-line analyses) that provide the starting conditions for the warfight. This integrated view of a maturing theater will provide visibility into the operational value of early C4ISR, strategic logistics, and alternative force flows.

The interaction and adjudication of BSEs in JWARS (*e.g.* sensing, attrition) is accomplished via a diverse set of algorithms that were provided to JWARS by domain experts or developed in-house. The nature and resolution of the algorithms vary, depending on the type of activity being modeled, the functionality in the model with which an algorithm is associated, and the availability of data to populate the developmental scenario. Figure 4 provides an overview of the types of algorithms and the interactions they address.

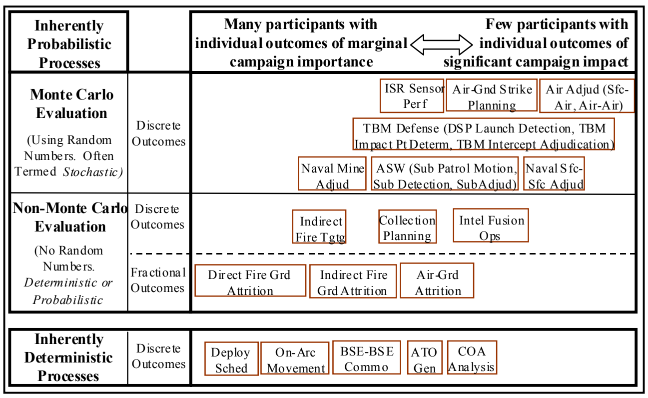

Figure 4: JWARS Algorithms

All of the interactions between BSEs in JWARS are scheduled as simulation events. The significance of individual events can range from relatively small (on the left side of Figure 4) to very significant (on the right). The deterministic algorithms address primarily the attrition of equipment in ground units. Individually, these types of events tend to have a relatively small impact on a campaign, and are accumulated using fractional outcomes. Cumulatively, however, these events could combine to have a significant effect (*e.g.* no halt occurs). There are also deterministic algorithms, such as collection planning, that do not lend themselves to fractional outcomes. At the other end of the spectrum (on the right of Figure 4), events that have a very significant impact on campaign level decision making, and success, are evaluated stochastically, also with discrete outcomes.

Figure 4 also provides two insights into JWARS. First, assessing the mix of algorithms is a way to evaluate the "balance" of the simulation. These algorithms adjudicate almost all "BSE-on-BSE" interactions in the model, and impact directly any measures of effectiveness that are collected. Therefore, it would be useful to compare and contrast different algorithms that evaluate similar physical phenomenon. (*e.g.* indirect fire vs. CAS) Second, all of the algorithms rely on either an accredited "feeder model" or an authoritative data source to support its operation in JWARS. In support of JWARS, the Joint Staff has identified many of the feeder models needed to build a JWARS database.

JWARS was designed from the beginning to be C4ISR centric. That means that BSE Command and Control is largely based on perceived truth, not necessarily on ground truth. This is an advance over many existing campaign level simulations in which command & control logic was based on ground truth.

The information flows in JWARS can be visualized using the Observe, Orient, Decide, Act (OODA) loop paradigm developed at the Air War College. Figure 5 illustrates the information flows that implement the OODA loop concept in the simulation system. This description begins in the bottom center of the loop and proceeds clockwise. JWARS, like all simulations, has a ground truth abstraction of the battlespace. This representation encapsulates all of the forces, their plans, possible behaviors, and the environment. BSEs in the simulation must be initialized with data that tells them what they perceive as truth concerning the opposing force. This process reflects steps from the operational Intelligence Preparation of the Battlefield (IPB) methodology and includes an initial collection plan.

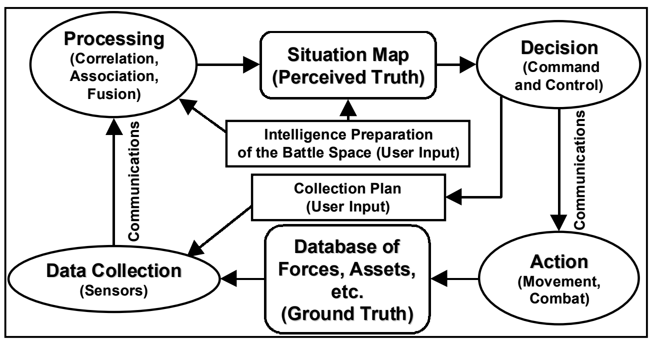

Figure 5: JWARS Logical Structure

During the observe phase of an OODA loop, BSEs use sensors to collect information on the opposing force. The quality of the information is a function of both the BSE sensor(s) and the signature(s) of the BSEs that are detected. Simulated command headquarters and staffs disseminate situation reports and adjudication results. These observations are packaged into reports and, via communications architectures, are sent explicitly to other BSEs (*e.g.* Joint Task Force Headquarters) in accordance with the concept of operations. JWARS communications models account for delays associated with all explicit messages. The magnitude of the delay varies with respect to the type of network and the background load on the network when the message is sent.

The processing and perceived truth nodes in the Figure 5 map to the orient concept in the OODA loop. The processing node represents the activity necessary to formulate a commander's perception. JWARS uses a set of pattern matching and fusion algorithms that combine new reports with previous perception; as well as introducing a processing, exploitation, and dissemination (PEDS) delay. The perceived truth node is analogous to a situation map. In JWARS it is called the JEF (JWARS Equipment and Forces). There can be one or more JEFs per side, allowing for the evaluation of concepts like the Common Operational Picture (COP).

The decision node in the figure represents JWARS Command and Control system is implemented in several ways. First, users input plans for the forces on both sides, such as the execution matrix that serves as a commander's decision support template. The JWARS model then makes high level decisions based on the current situation using these templates during execution. For instance, a counterattack is scheduled to begin on Day D using unit X. The user inputs this event with other decision criteria (*e.g.* unit strength, or location). On Day D of the simulation run, the C2 evaluates the ability of a unit to initiate its assigned mission based on the input criteria. If the unit cannot comply with the execution matrix, the C2 logic of the simulation reports that the force is "off-plan" and corrective action is warranted. Next, rule processors, run-time mechanisms for making decisions in JWARS, allow users to change parameters of key C2 related variables in the model. These decision rules are based on subject matter expert input. Planners and behavior templates also generate tasks and plans to be executed over some time horizon. Examples include the Air Tasking Order (ATO) generator, collection planner, strategic lift scheduler, and maneuver sequence planner. Finally, decision rule sets enumerate phase and state-change situations for the Joint Task Force level command and control.

The final node in the OODA process is the action node. While actions are being adjudicated based on ground truth, JWARS updates the ground truth database.

2.2 Simulation Domain

The Simulation Domain contains the functional infrastructure that incorporates the event list, random number generators, coordinate systems, and data collection agents. Referred to as managers in JWARS (see Figure 6), these mechanisms are object-oriented code that software engineers create and implement JWARS problem domain functionality. The JWARS modular design will allow future users to implement new concepts relatively easily. The Smalltalk™ development environment also allows the distribution of computational requirements to multiple processors, enabling future JWARS versions to capitalize on rapidly emerging advances in distributed and parallel computing.

Manager	Function
Spatial	Geo-spatial filter that minimizes battle space interactions
Movement	Controls movement of BSEs
Interaction	Informs BSEs when they might "see" each other
Environment	Informs BSEs about the physical environment in which they operate
Adjudication	Assess outcomes of combat
Event	Manages time and activities
Data Collection	Collects data during simulation
Simulation	Ties all software components into single simulation

Figure 6: Simulation Domain Components

The simulation domain also provides a computerized synthetic natural environment (SNE) for the BSEs to move in and react with. This battlespace maps to the WGS-84 ellipsoid, and uses the Global Coordinate System (GCS). This representation allows a globally-consistent location of all JWARS entities. Affecting the performance of military units and systems are terrain, weather, mobility networks, bathymetry, visibility, sea state, terrain roughness, and wind. In a typical JWARS run, there are thousands of calls made to the environmental manager for relevant information. Terrain, acquired from standard NIMA data sets, is stored in Compact Terrain DataBase (CTDB) format. It is processed using ERDC Vicksburg-developed algorithms for converting user-defined maneuver cells and a mobility network that supports intratheater movement. Weather data is derived from the Defense Modeling and Simulation Office (DMSO) Environmental Scenario Generator (ESG).

The JWARS Operational Requirements Document (DoD 1998) has very demanding traceability requirements with respect to both input and output data. Meeting these requirements necessitates the inclusion of a robust database management system. JWARS meets these requirements using ORACLE™ as the database engine. Both input and output data are stored in ORACLE™. Most of the data are in binary form and requires the JWARS HCI to view and manipulate. The HCI then provides tools and controls that meet the prescribed traceability requirements.

Similar to other developing DoD simulations, JWARS is required to be HLA/RTI compliant. This requirement will be met in part through a Run-Time Interface (RTI) binding that is part of the IBM Visual Age Smalltalk™ development environment. This will allow simulation federations that involve JWARS to be developed relatively easily. Additionally, other simulations that use Smalltalk™ will be able to reuse the RTI binding, potentially reducing their development cost.

2.3 Platform Domain

The JWARS platform domain includes the hardware on which the simulation runs and the Human Computer Interface (HCI) which users interact with to control the simulation. The HCI is used to support scenario construction, Intelligence Preparation of the Battlefield, run control, and output analysis. Most analytic requirements can be met by interacting with the simulation using the HCI.

JWARS collects data using instruments that are provided by the simulation domain. JWARS users can select the data they wish to collect through the HCI. During simulation execution the data is then collected and stored in ORACLE™. After the run, analysts can visualize the results through a limited set of analysis tools that are organic to JWARS. Additionally, any instrument that is collected can be exported as a delimited file for use in COTS analysis tools. During initial JWARS testing, the participating analysts developed many tools to view the data.

3 JWARS ISSUES AND LIMITATIONS

JWARS is working to the state-of-the-art in operational level combat modeling. That said, there are modeling issues and limitations that have implications for potential JWARS users.

First, the JWARS algorithms, although "validated" by the submitting service or proponent, may not be globally consistent. For example, the assumptions in the indirect fire algorithm (and its feeder model) may not be compatible with the assumptions in the air-to-ground attrition algorithm (and its feeder model). The second is a corollary to the first issue. Previously, "balance" in JWARS has been defined by the warfighting functionality identified in requirements documentation.

This view, while extremely useful to support development, does not ensure that the data and algorithms representing similar physical events are of compatible resolution. The third modeling issue is data. The issue has both technical and managerial aspects. Technically (again a corollary to the first issue), the data needs to be consistent across military domains and compatible with the environmental data that supports the simulation. On the management side, JWARS demands unprecedented quantities of data to construct a working scenario. Figure 7 depicts the all of the processes and tools used to build a JWARS scenario. The Joint Data Support (JDS) initiative has been the foundation in meeting this demand that requires human data analysts and research resources.

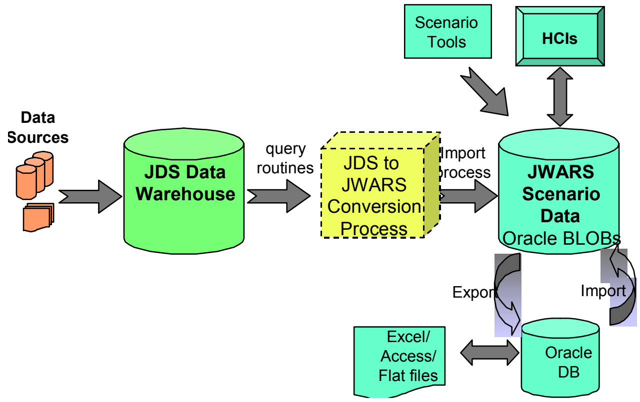

Figure 7: Meeting a Challenge in Data Needs

JWARS is a new tool that implements many new modeling concepts, and is tremendously complex. The complexity of the model is a function of the complexity of the multi-billion dollar "system of systems" we are attempting to describe. That said, there is a significant (albeit necessary) learning curve. It will take some time to develop a core team of analysts that are proficient with the tool. It will be slightly longer until an experienced user base is prepared to present "end-to-end" JWARS results to senior leaders.

3.1 Summary

JWARS will provide analysts with an excellent foundation for conducting analyses and research in support of the US DoD. The limitations of the tool reflect the current knowledge boundaries of military modeling and simulation technology. The modeling advances that have been achieved in JWARS can enable research into emerging concepts and doctrine.

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AUTHOR BIOGRAPHIES

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