

## VERIFICATION OF OBJECT-ORIENTED SIMULATION DESIGNS

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### ABSTRACT

This paper discusses the verification process for object-oriented simulation high-level and detailed designs based on the authors experience with the Joint Warfare System (JWARS). There is an overview of the JWARS simulation, the software development process, and the design artifacts. The paper describes how the JWARS V&V Team developed a tailored process and method for verification of the high level design and the detailed design and attempted to determine and document the completeness of the design. Also the V&V Team's verification experts attempted to identify the linkage and traceability of the simulation from the pre-design artifacts to the design and from the design to the implemented code. Included is a discussion of how JWARS uses the IBM VisualAge and UML Designer tools and how the Verification Agent was able to use them to support the verification process.

### 1 VERIFICATION

This paper specifically addresses the process and procedures used for JWARS design verification. DoD regulations and instructions (including DoDD 5000.59 and 5000.61) define verification as the process of determining that a model implementation and its associated data accurately represents the developer's conceptual description and specifications. The 1996 version of the *DoD VV&A Recommended Practices Guide (RPG)* calls verification the process of determining that a model and its resultant simulation accurately represent what is required and how the M&S developer plans to build the simulation.

For the JWARS V&V process verification is focused on the high level design (HLD) and the detailed design (DD). The following sections describe the JWARS simulation, the JWARS V&V process, and the JWARS design verification process.

### 2 THE JOINT WARFARE SYSTEM (JWARS)

The JWARS simulation is being developed by the US Department of Defense's (DoD's) Office of the Secretary of

Defense (OSD) for use in theater level warfare analysis. In May 1995 the Deputy Secretary of Defense approved the Joint Analytic Model Improvement Program (JAMIP) and directed OSD's Program Analysis & Evaluation Directorate, in cooperation with the Joint, to develop a state-of-the-art, closed-form simulation of joint, campaign-level warfare. JWARS is required to: represent uniquely joint functions and processes, and component warfare operations; be based on joint doctrine; and, be capable of representing future warfare.

Future users of JWARS will include the Joint Staff, the US military Services, the US regional and functional combatant commands, OSD, Joint Task Forces, other DoD organizations, and industry. The planned JWARS applications include: force assessment; force planning and execution (both deliberate planning and crisis action planning); system effectiveness and trade off analysis; and, concept and doctrine development and assessment.

JWARS development began in April 1997 and the Verification & Validation (V&V) effort began in September 1997. One of the primary tasks of the V&V Agent, as detailed in the JWARS V&V Plan (JWARS Office 1998), is to verify the JWARS design artifacts. JWARS development is approaching Limited Initial Operating Capability (IOC) sometime in 2002. Release 1.3 has been distributed to several future user sights for familiarization and training. Release 1.4 will be released for beta testing at 13 user sights later in 2001. Fixes of the beta test version included in Release 1.5 are expected to make up the Limited IOC version of JWARS. JWARS requirements are contained in the JWARS Operational Requirements Document (Joint Staff, J-8 1998). Information about JWARS is provided in the JWARS Overview Briefing available at <https://www.jointmodel.mil>. (JWARS 1999) This paper addresses the design verification activities conducted to date for JWARS Release 1.2 and planned for Release 1.3 and future releases.

### 3 JWARS V&V PROCESS AND PLAN

Immediately after the JWARS V&V effort began in September 1997 the JWARS Office formed the JWARS V&V Oversight Group. Since that time this group has evolved into the

combined JWARS V&V and Test and Evaluation Working Integrated Product Team (IPT). The first task of the group, co chaired by the JWARS Office and the V&V Agent, was to develop the JWARS V&V process shown in Figure 1 and described in the JWARS V&V Plan. (JWARS Office 1998)

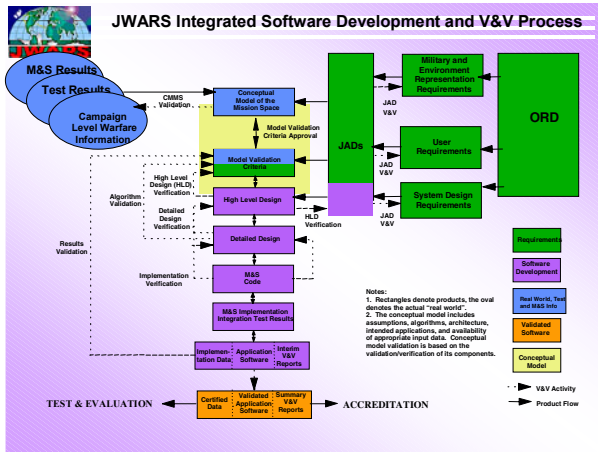


Figure 1: JWARS V&V Process

The JWARS V&V process includes pre design artifact V&V, design verification, and results validation. The pre design artifacts include the Joint Application Design (JAD) packages (or packets) that are the first step in developing the derived requirements that will be included in the design. Other pre design artifacts include the Conceptual Model of the Mission Space (CMMS) that is provided by the JWARS Enterprise Model and the algorithm descriptions. The verification processes for the JWARS high-level design and detailed design are described in detail in the following sections.

#### 4 JWARS HIGH LEVEL DESIGN (HLD) VERIFICATION

systems or components interact to make the systems work. The HLD is developed by the JWARS Developer and is based on:

- Mission space representation requirements that flow from the real world
- Intended use
- System design requirements

The HLD provides a level of design required to understand how the components of the product technically work and whether the planned functionality for the software addresses mission space and system design requirements. The purpose of HLD verification is to ensure that mission space representation requirements, given JWARS' intended use and system design requirements, are addressed in the planned functionality for software models.

The execution of the High Level Design Verification Process (HLDVP) as shown in Figure 2 is to ensure functional traceability from the High Level Design, through the Joint Application Design (JAD) packages, back to the user requirements that are explicitly delineated in the JWARS Operational Requirements Document (ORD). Furthermore, the process is designed to verify that the design includes the behaviors of battlespace entities that are dictated by Service and Joint strategic, operational and tactical doctrine (the focus being on the strategic and operational levels) and that are represented in the Enterprise Model. The HLDVP assumes that the JAD Reviews conducted by the Subject Matter Experts (SME) and system users have reconciled the requirements in the ORD with user requirements and doctrine and that the Thread Intent Statements and other statements of required functionalities and interactions articulated in the JAD Packages accurately reflect these reconciliations.

The JWARS Simulation is being implemented as an objected-based system. The development effort is based on the Unified Modeling Language and the artifacts that devolve from use of the language. Two UML artifacts, Use Cases and Use Case diagrams, are effective mechanisms being used by the developers for explicitly delineating the behaviors that the system is required to represent. The Use Case is a natural language description of an interaction between an entity outside the system and the system being built. Use cases describe how the system will be used and in general trace a particular task from start to finish. A Use Case Diagram gives a visual representation of the system being designed, its actors and Use Cases, and their relationships. More specifically, a Use Case represents the definition of a system behavior that when implemented in the system will provide the functionality and simulate the Enterprise behaviors articulated as user requirements in the JAD Packages.

Based on the foregoing notions, the High Level Design documents should contain natural language reitera-

#### JWARS High Level Design Verification Process

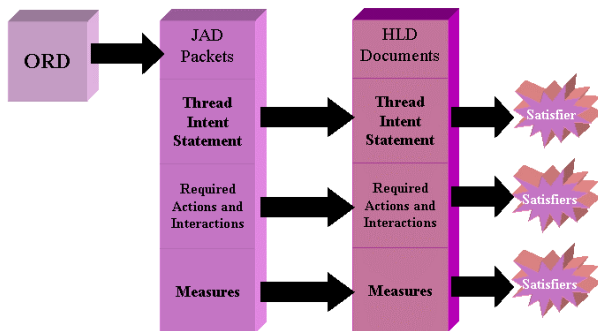


Figure 2: JWARS HLD Verification Process

HLD development is the first step in the design stage for solving the “problem” -- making decisions on how the sub-

tions of the Thread Intent Statement, statements of the reactions and interactions among entities, and the measures of behaviors of interest to the users, that are identical to those contained in the JADs. Furthermore, the High Level Design documents should identify Use Cases that, when implemented, will provide the system functionalities that meet (satisfy) ORD, user, and JAD representation and simulation results (output) requirements. The HLDVP was structured and employed to assess whether or not the High Level Design documents contain these features.

The HLDVP that the V&V agent employed consists of 3 steps:

1. JAD Packet “Thread Intent Statement” — compare with HLD Thread Intent Statement and trace to a satisfier (High Level Use Case).
2. JAD Packet “Required Actions and Interactions” — compare with HLD Required Actions and Interactions requirements and ensure each has an identified satisfier (Use Case).
3. JAD Packet “Post-Processing Measures” — compare with HLD Measures identified in HLD and trace each requirement to a satisfier (Use Case).

Throughout this process we look for any use cases in the HLD that does not satisfy a stated JAD requirement. These use cases are to be brought to the attention of the JWARS Office for a determination as to whether or not a new requirement should be added to the JAD Packet or the use case is out of scope and should be dropped.

## 5 JWARS DETAILED DESIGN VERIFICATION

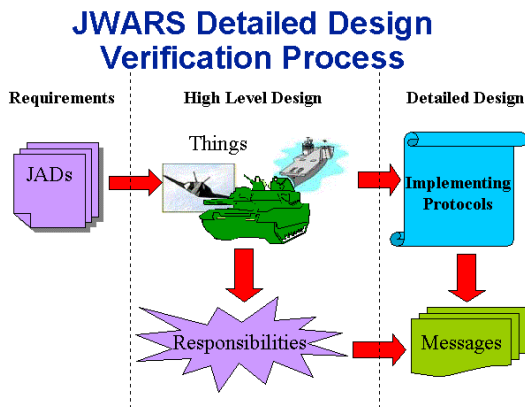


Figure 3: JWARS DD Verification Process

The Detailed Design provides the information a software engineer needs to write code. This includes sequencing information, algorithms, assumptions (mathematical, structural, and causal), interface protocols, data, etc. Each element of the Detailed Design must be traceable to the High

Level design (HLD), and vice versa. The Detailed Design verification process is shown in Figure 3.

The objectives of JWARS Detailed Design verification are:

- To ensure that the content of the Detailed Design is complete
- To ensure that each component of the Detailed Design traces to the HLD and appropriate JAD packet
- To assess whether the algorithms or mathematical approximations specified in the Detailed Design are sufficiently accurate vis-a-vis the real world, considering their intended uses
- To determine the operational and analytical implications of the identified assumptions

The V&V Agent, working closely with the JWARS Developer, has primary responsibility for conducting Detailed Design Verification.

The JWARS Detailed Design Verification process is to use IBM’s VisualAge UML Designer to trace High Level Design “Things” and “Responsibilities” derived from JAD Packets to Detailed Design implementing “Protocols” and “Messages.” IBM’s VisualAge UML Designer is a tool for capturing and organizing requirements and object-oriented design information, as **models**. These models are comprised of:

- **Things** - an entity inside the system. Things are candidates to become objects in the eventual implementation.
- **Responsibilities** - a duty of a thing, something it must do in order for a use case to complete successfully.
- **Protocols** - a specified object interface. A protocol consists of a set of message specifications that describe what messages an object must understand, what their parameters are, and what their return values will be.
- **Messages** - an element contained within a protocol. Message specification can be generated from a responsibility, or it can be reversed engineered from an implemented method (as is the case in JWARS Detailed Design).

The JWARS Detailed Design to date has been reversed-engineered from the SmallTalk code in the implemented simulation. An overall verification analysis report is then generated from the JWARS V&V Database identifying those “Things” and “Responsibilities” required by the JADs and the High Level Design that appear to be supported or unsupported by the model implementation.

Reverse-engineering the JWARS Detailed Design from implemented JWARS SmallTalk code makes it very difficult and time consuming to perform detailed design verifica-

tion. We had to adopt a manual process of attempting to visually match elements from the HLD to what was actually implemented in the model since model implementation was not directly based on the design itself. A detailed verification analysis report was generated from the JWARS V&V Database identifying those “Things” and “Responsibilities” required by the JADs and the High Level Design that appear to be supported or unsupported Detailed Design.

## 6 SUMMARY AND CONCLUSIONS

The JWARS V&V Team has been able to develop effective design verification techniques for the JWARS V&V process. Although the process requires more manual actions than planned, we are able to trace the design from the validated pre-design artifacts to and through the high level design to the detailed design. In addition, the mission space behaviors required can be found and identified in the high level design and the subsequent detailed design. We are currently working with the developer to develop a method to streamline this manpower intensive process by automatically publishing detailed design artifacts with UML Designer into a format more readily imported into our MS Access V&V Database. One advantage of reverse engineering the detailed design from the implemented simulation is that the design contains artifacts that directly correlate to the implementation negating the need for implementation verification. Also, based on V&V Agent recommendations the developer is currently revamping their development process to address some of these shortfalls. This new process should contain improved traceability from ORD Requirements, JWARS Stated and Derived Requirements, Use Cases, High-level Design Class Specifications, and Detailed Design Supporting Class Specifications. Object oriented design products can be effectively verified using the techniques described, supporting both development risk reduction and the building of the body of knowledge required by future users in their simulation accreditation process for an intended use.

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