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Lessons Learned using the JNTF Verification & Validation Process

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The JNTF has defined a cost-effective, tailorable, and scalable V&V methodology which this past year was effectively used on the first release of a missile defense system simulation. We will present the lessons learned from applying the methodology on the National Missile Defense (NMD) High Fidelity System Simulation (HFSS). This effort was presented with numerous technical and programmatic challenges, and the adaptability of the JNTF V&V Methodology contributed to the success of the effort.

The HFSS is a missile defense simulation that covers all aspects of performance modeling from threat launch, space-based tracking, ground radar tracking, battle planning, and interceptor launch. It is intended to support system engineering studies and analyses while the system is in the early requirements definition and system design phases.

The methodology produced a V&V report that provided a well received assessment of the capabilities and limitations of the simulation. It is clear that the use of a well defined and adaptable process contributes to the quality of the product while addressing the numerous technical and programmatic challenges.

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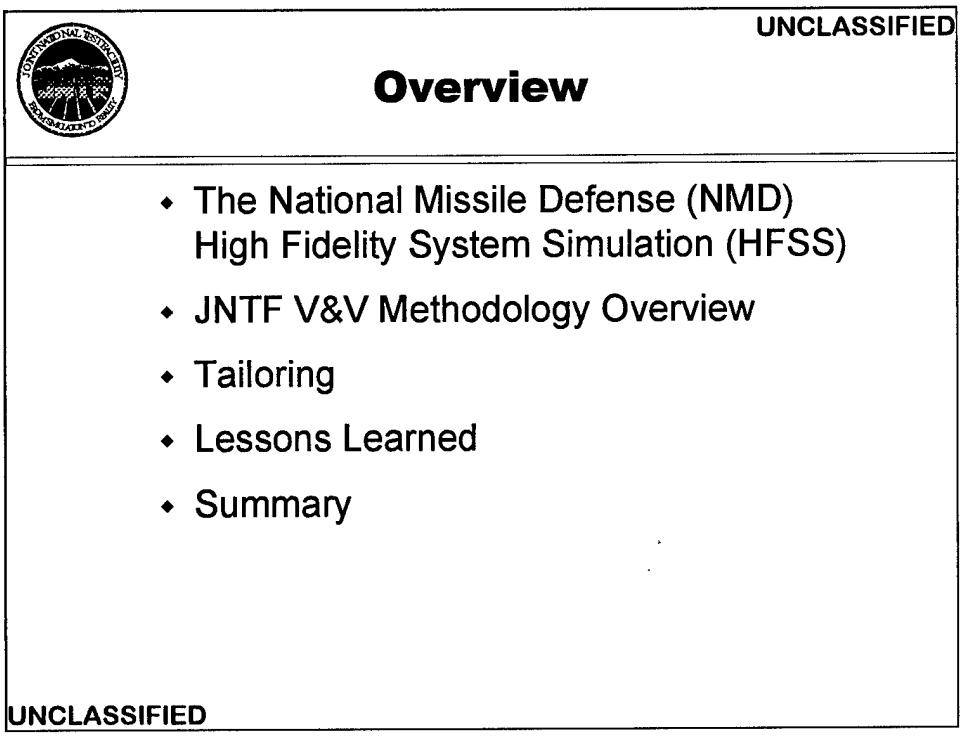

Models, simulations, and testbeds are now an integral part of weapon systems design and development as well as test and evaluation. The ultimate effectiveness of weapon systems therefore depends more and more on the validity of models used in their acquisition. Over the past ten years, the Joint National Test Facility (JNTF) has developed a methodology for the Verification and Validation (V&V) of models, simulations and testbeds and has evolved it using insights gained through its use in numerous assessments. This presentation describes how the JNTF V&V methodology was used on the National Missile Defense (NMD) High Fidelity System Simulation (HFSS).

A description of HFSS will be provided to establish the context for this project. A overview of the JNTF V&V methodology will provide greater understanding of the breadth of procedures available within the methodology. A discussion of the tailoring will show how specific procedures can be selected based on cost or schedule constraints. The lessons learned provide insights that are applicable to many V&V efforts, and may provide help to other V&V practitioners in the missile defense community.

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HFSS Overview

- HFSS is an end-to-end NMD simulation (Threat Launch to Negation or Impact)
- HFSS intended use
  - Systems engineering studies
  - System performance verification
- Developed by the NMD Systems Engineering Contractor
- Verification and Validation performed by the JNTF and the Naval Surface Warfare Center

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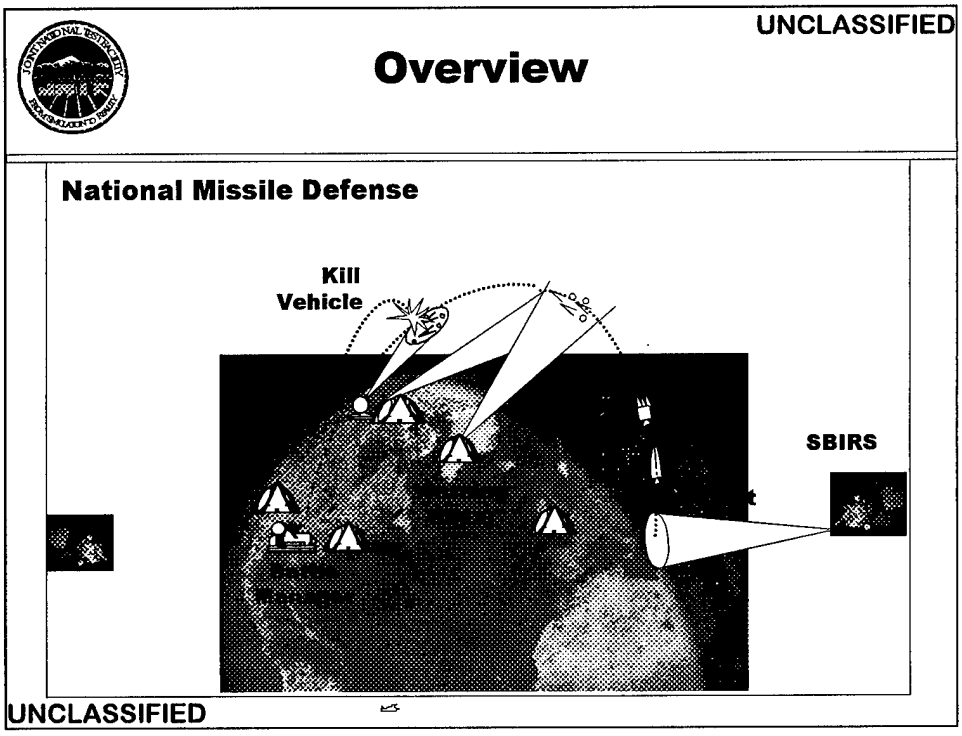
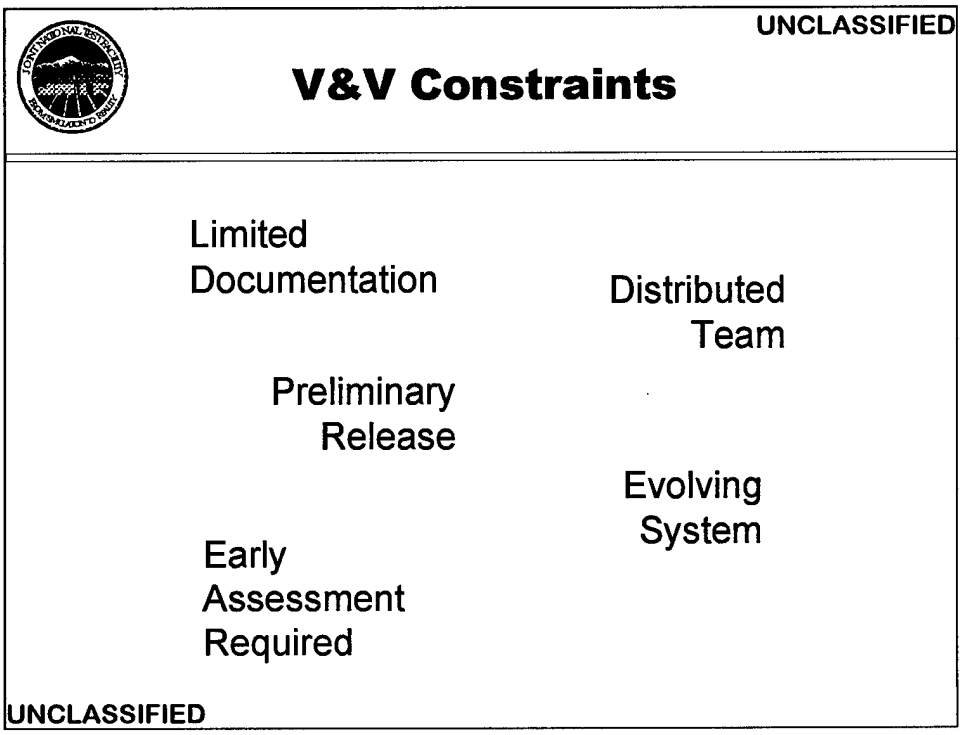
HFSS provides an end-to-end simulation of the National Missile Defense architecture. It was intended to be used by the Systems Engineering organization to study architecture issues, requirements trades, and to evaluate the performance of the proposed system.

The simulation was built by the NMD Systems Engineering and Integration Contractor. The V&V was assigned to the JNTF with support from the Naval Surface Warfare Center, Dahlgren Division.



This diagram shows the scope of the NMD system as simulated in the HFSS. HFSS simulates the launch of threats using pre-approved threat data. These threats are then detected by a Space Based Infra-Red System (SBIRS), which provides initial warning messages to the Battle Manager. Later detection and tracking is performed by the early warning radars, which then provide queueing to the tracking radar. Based on the satellite and radar data, the battle manager develops an engagement plan, and then tasks the weapons to launch exo-atmosheric kill vehicles to destroy the threat.

The HFSS release used in this effort implemented only low-fidelity versions of the element models. As a first release, it was built to establish the overall simulation architecture. Future plans called for incorporation of high-fidelity models, but a change in contractors resulted in no further work on the HFSS.



Tailoring provides the greatest level of confidence to the customer, within the constraints of the project. Careful review, and interaction with the customer, results in a V&V effort which provides an acceptable level of confidence while accounting for the resource constraints.

The contraints placed on this particular effort were severe, and only allowed for a limited evaluation of the simulation.

The most critical constraint effecting this effort was the need for an early assessment of the HFSS capabilities. The customer wanted to know at an early date the state of the simulation and its applicability to potential users. This meant that the V&V effort was based on a preliminary release, built to the evolving requirements of the proposed NMD architecture. This also meant that the documentation was incomplete, so the primary artifact available for evaluation of the system was the software itself (that is, there were no design materials).

Another constraints was the use of two government organizations for the V&V. The meant that tasking had to be worked out between the JNTF in Colorado and NSWC in Virginia, and that the team had to remain coordinated and in regular communication.

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JNTF V&V Methodology
39 Procedures Available

Conceptual Validation	Software Verification	Operational Validation	Data Validation
• Development history analysis • Model derivative analysis • Previous model use analysis • Requirements criticality analysis • System analysis • Modeling concepts analysis • Input/output fidelity analysis • Algorithm analysis • Logic trace analysis	• CASE and design methodology adherence analysis • Screening procedure • Process metrics analysis • Products metric analysis • Internal software testing analysis • Code analysis • Security code analysis • QA review • Documentation review • User support review • Model flexibility assessment • CM Review • IV&V Review • Graphical display evaluation	• Animation test • Fixed value test • Simplified assumption testing • Extreme condition testing • Predictive validation testing • Output validation analysis • Comparison to test data • Sensitivity analysis • Feedback loop analysis • Event sequencing testing • Head to head comparison • Input/output relationship analysis	• Input data analysis • Data consistency analysis • Portrayal of constants analysis • Distribution form analysis

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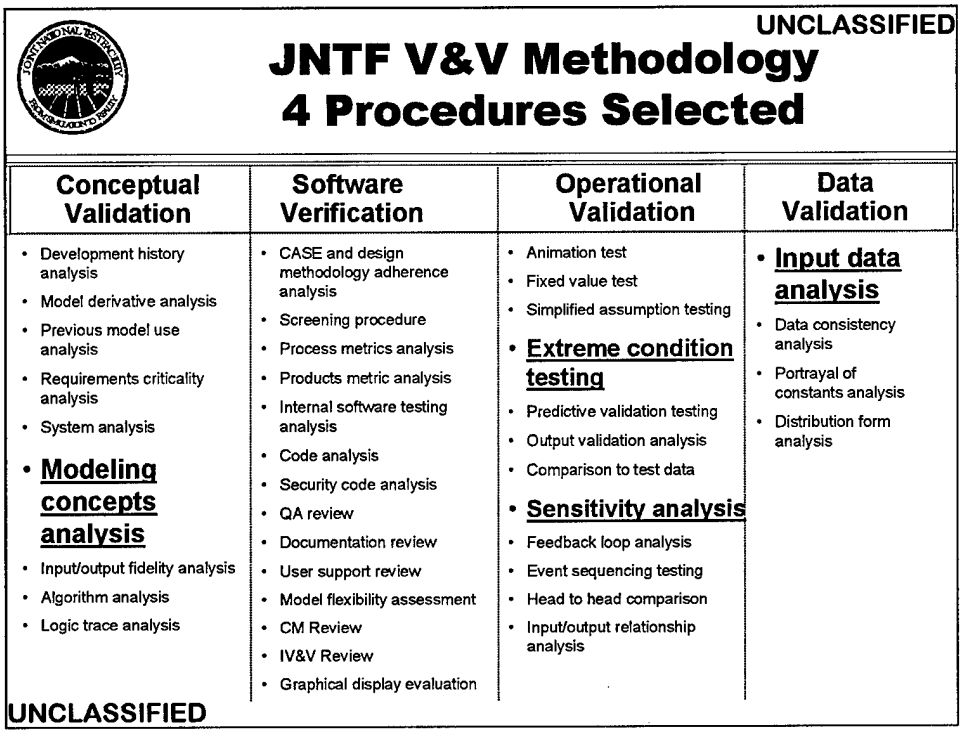
The JNTF has been performing V&V on models and simulations used for Ballistic Missile Defense (BMD) since 1988. The procedures used have been documented and institutionalized so that future projects could spend more time on engineering and less on developing procedures and so that the JNTF V&V efforts would be repeatable. Over time 39 procedures have evolved and proven to be scalable to a variety of V&V efforts. Although there is not a one-to-one correspondence between the JNTF procedures and those in the newly released DMSO Recommended Practices Guide, there is a close correspondence. In general, the JNTF procedures have been documented in substantially more detail than those of DMSO.



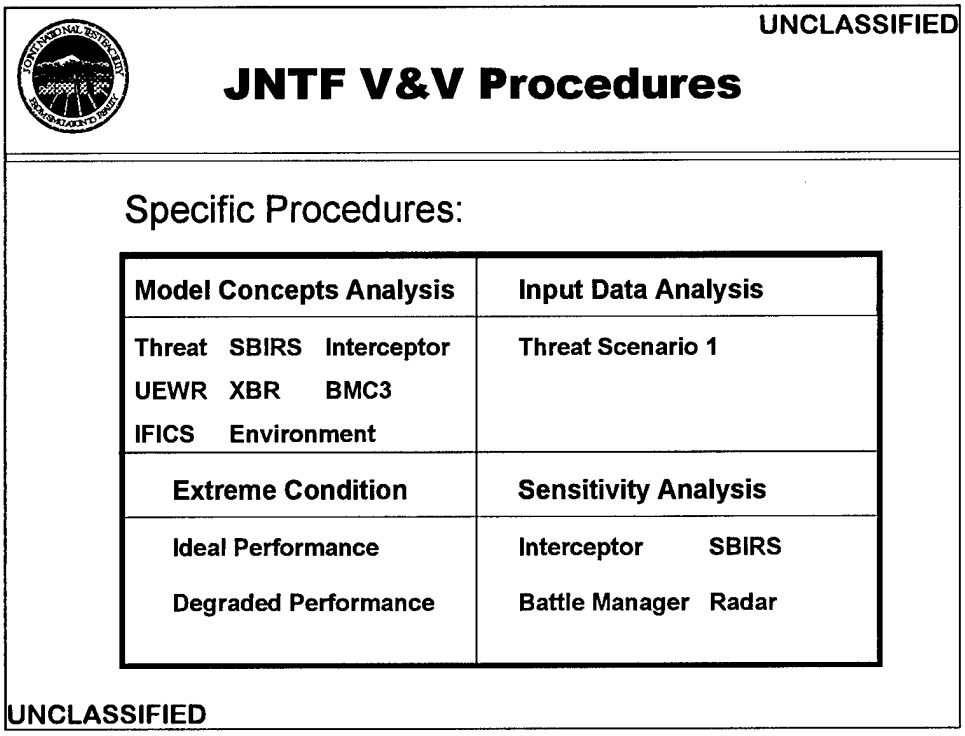
Of the 39 procedures, 4 were selected for use on the HFSS.

Modeling Concepts Analysis is intended to be a review of the model implementation to assess whether or not the selected methodology elements are consistent with the goals for model application as represented by the intended use statement. In particular, fidelity, repeatability, data availability, and code capability are reviewed.

Knowledge of model behavior under extreme input conditions is important not only at the time of model selection and data entry, but also as an indication of how adaptable the model may be to other non-design uses. This procedure will investigate the nature of input, model behavior under extreme conditions, and how thoroughly and adequately this behavior was documented.

Sensitivity Analysis examines a model's sensitivity to incremental changes in input or internal variables. Any variable to which the model is particularly sensitive is examined more closely to determine if it has been modeled correctly.

Input Data Quality Review determines if the: (1) input data supports the intended application, (2) source(s) of input data is/are credible or officially sanctioned, and (3) input data is reliable and current. Input Data Quality Review focuses on the model at the vertical level, examining a particular aspect of the model in detail.



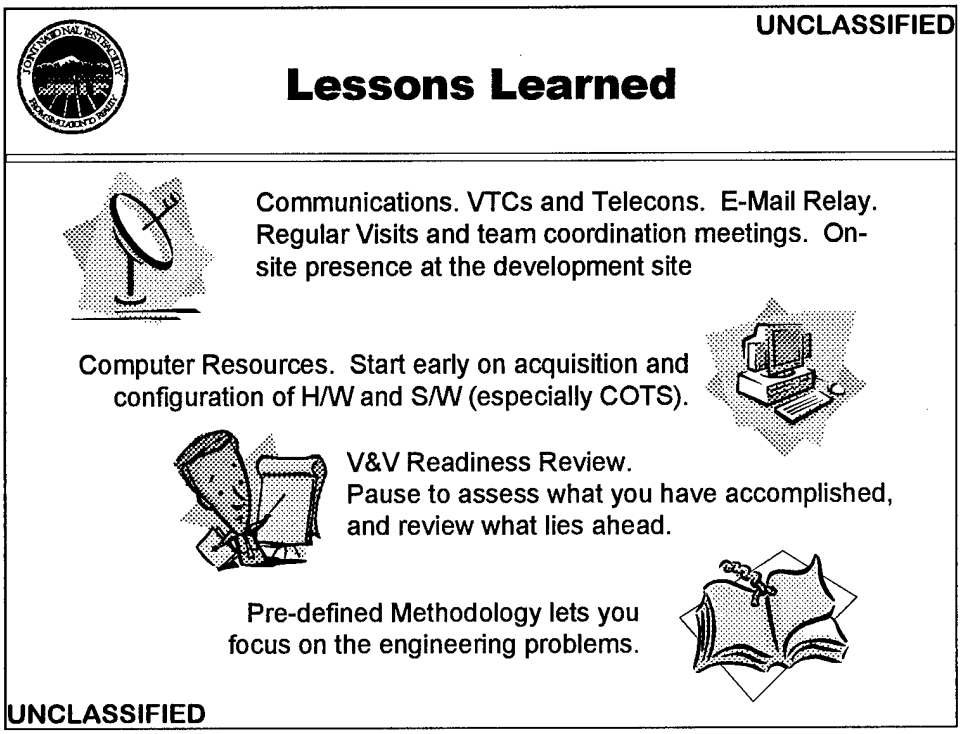
Each of the four procedures was then executed for specific models or conditions.

The Models Concepts Analysis was performed for each major sub-system modeled in the HFSS. This was a detailed review of the design and implementation of the model.

The HFSS organizes it databases around threat scenarios, although it also includes all of the data needed for all of the simulated sub-systems. In this case, Threat Scenario 1 was built by the developer, and then used to develop all other test case databases. Verification of this database provided confidence in all of the other test case databases.

Because of constraints on time, system level extremes were performed. In the ideal case, all weapons and sensors worked in an ideal manner. Probabilities were set to 1.0 to enable ideal results. The degraded run provided failures on individual sub-systems to demonstrate the impacts at the system level.

Sensitivity analyses were performed for the to evaluate model performance in 4 key areas: interceptor, SBIRS, Battle Manager, and Radar.



Communications is critical to a team effort, and it is even more critical when geographically dispersed. Regular team meetings were held each week via telecon or video teleconferencing. We didn't always have a planned agenda, but it was still valuable to get together. Also, regular site visits, at least monthly, provided an opportunity for more detailed communication and coordination.

Computer resources for a V&V team are essential. We started early in our acquisition process. Just-in-time is most likely a-little-too-late. It was important to try out hardware and software configurations before critical need dates. The use of COTS in simulation development is a new trend, and it means the V&V team must have a proper configuration. We found that supposedly backward compatible versions are not always compatible.

We held a V&V Readiness Review as we started our final V&V effort. At this point, we had been running the simulation for 2 months, and performing dry-runs of specific procedures. The VRR provided a chance to asses the breadth and depth of our effort before getting too close to our end date.

The JNTF methodology made our planning and execution easier. We were focused on the engineering problems instead of process design.

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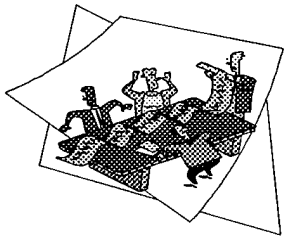
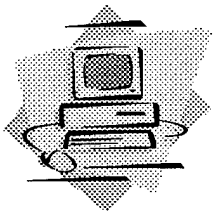
Lessons Learned

Document Production. With a team, you have different format and submittal requirements. Give organizational credit.



Final Assessment and Interpretation of results. Half empty or half full ? The Intended Use is critical.

Do not apply standards for Operational Software to a Computer Simulation



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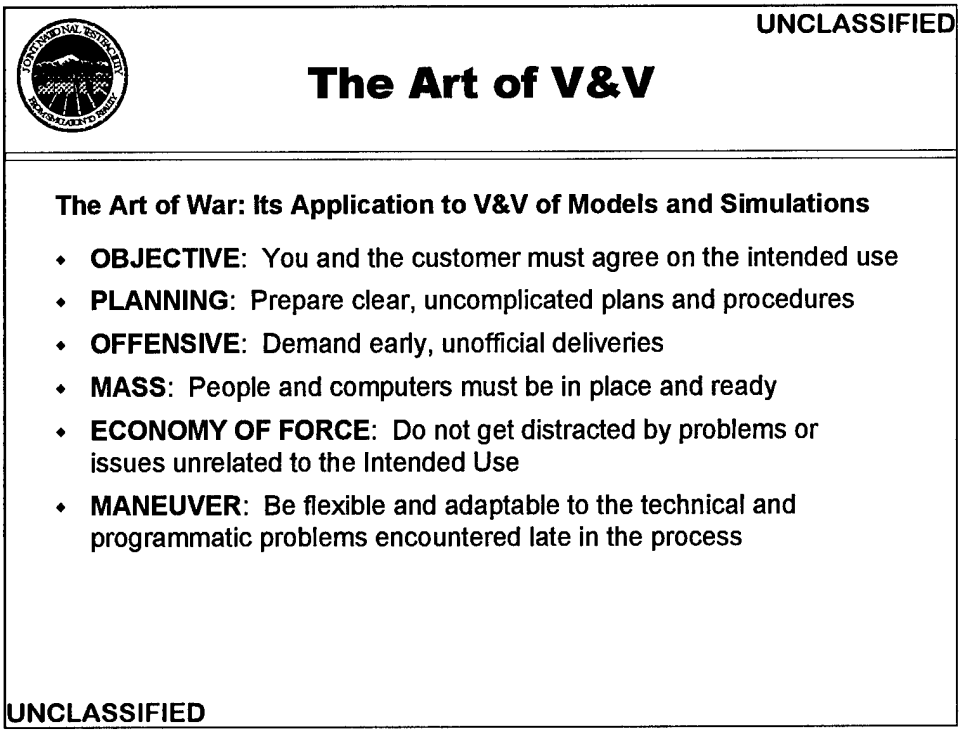
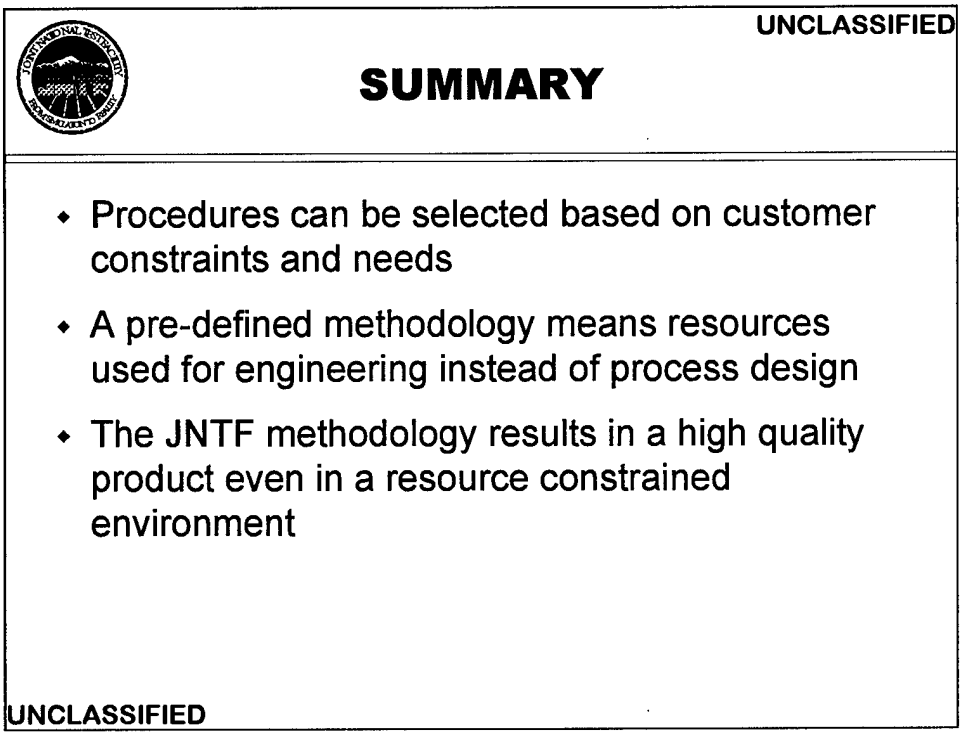
Document production is critical to having the body of evidence needed for accreditation of the simulation. It is important, especially in a team environment, to work out early the logistics and mechanics of document production and submission. It is especially important to understand management review and approval requirements.

Understanding the Intended Use, especially of preliminary releases, is important. We had ambiguities that led to disagreement on our findings. This also relates to the different organizational cultures.

The V&V team must remember that a simulation may not need to meet the same quality requirements as an avionics package. It is a waste of resources to evaluate against requirements that are too stringent.



While working this project, a small poster summarizing Sun Tzu's "The Art of War" was posted in our work area. Some of the lessons from the Art of War are applicable to V&V. In this case, the enemy is not the developer. The enemy is a bad or incorrect simulation. Applying these concepts can help in performing V&V.



Having a set of procedures defined, documented, and institutionalized provides clear benefits to a V&V team. Time is not wasted in defining "how" to proceed with V&V; the analysts can quickly focus on the engineering issues. Specific techniques can be selected for the effort to minimize risks, or to increase the analysis of critical areas. The JNTF V&V Methodology has proven to be an effective tool for obtaining a well balanced, comprehensive product in a resource constrained environment.