A System Simulation to Enhance Stockpile Stewardship (ASSESS)

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Abstract
This paper describes the ASSESS project, whose goal is to construct a policy driven enterprise simulation of the DOE nuclear weapons complex (DOE/NWC). ASSESS encompasses the full range of stockpile stewardship activities by incorporating simulation component models that are developed and managed by local experts. ASSESS runs on a heterogeneous distributed computing environment and implements multi-layered user access capabilities. ASSESS allows the user to create hypothetical policies governing stockpile stewardship, simulate the resulting operation of the DOE/NWC, and analyze the relative impact of each policy.

Introduction

Sandia's Systems Departments are chartered to study issues of importance to national security. Many DOE/NWC players (production, testing, development) stand to benefit from a policy driven simulation tool that pulls together all aspects of the enterprise to support decision directed analysis. The goal of such analysis is to characterize and quantify the impact of hypothetical policies related to stockpile stewardship.

Over the past two years, the Exploratory Systems and Development Center developed a simulation prototype that supported both stockpile stewardship and health care enterprise models (work was partially funded by a CRADA with the Kaiser Permanente HMO). That prototype successfully unified weapons reliability calculations and science based materials modeling with variable test policies. However, the prototype showed that the resource capabilities of a single workstation class computer are inadequate for the massive amount of data associated with a simulation of the DOE/NWC. ASSESS builds on the experience of the prototype, but implements a new design capable of simulating the entire DOE/NWC.

Software System Architecture

The ASSESS enterprise simulation of the DOE/NWC is actually a confederation of component simulation models, each constructed and managed by local experts. Accurate detailed information resides in the component models, and ASSESS provides a software framework allowing the components to interact. Currently, component models include:

- Pantex process model, developed under E. Kjeldgaard of SNL
- transportation planning model of the TSD, developed under J. Roesch of SNL
- neutron tube production and planning model, developed under E. Yarasheski and J. Bechdel of SNL
- NWC enterprise model, developed under G. Mann of SNL.

ASSESS allows component models to execute on any machine that can be connected to the main simulation. This is accomplished by cooperatively adhering to a published API for each model, and connecting the executing processes through CORBA/Java interfaces (Figure 1). External model interface support will be provided for:

- arbitrary C/C++ source code
- Microsoft Access databases
- Microsoft Excel spreadsheets
- Extend simulations
- ithink simulations.

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Quantitative Example

This example demonstrates the interplay between a science model that predicts component aging, weapon reliability, and policies for component replacement. The science model describes the metal thickness of a solder joint as it decreases over time. The rate of decrease depends strongly on the temperature the weapon experiences during its lifetime.

Figure 2 is a snapshot of the metal thickness of each simulated weapon on a particular date, plotted against the integrated temperature-time history of each weapon. In general, the higher the temperatures experienced by a weapon, the smaller the metal thickness, and the more likely the critical thickness (which causes component failure) has been reached.

The effects on the overall weapon reliability were simulated for three different policies. The first policy dictated that ten weapons are chosen randomly each year for testing. In testing, the metal thickness is measured, and if any thickness is below the critical thickness, the affected component is repaired in all weapons. For the second policy, ten weapons are also chosen every year, but the selection is based on temperature history instead. The individual weapons which have seen the highest cumulative temperature histories are chosen for testing. As before, a repair program for all weapons is initiated when a sub-critical metal thickness is found.

As a baseline, a third policy is simulated in which no testing occurs. In this scenario, the system reliability decreases continually as the metal thickness in each weapon diminishes with time (Figure 3). With the random selection policy, the system reliability decreases until a defective weapon is tested. The system reliability then recovers as the weapons are repaired. As the newly repaired weapons age, the reliability again decreases and the cycle continues.

With temperature based selection, defective weapons were found sooner than with random selection. Because of the earlier detection, the system reliability was maintained at a higher level.

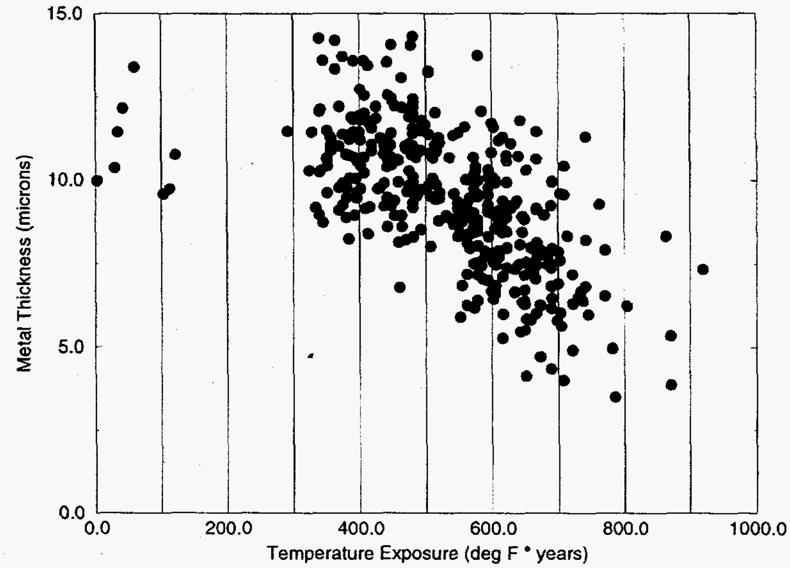

Figure 2. Metal thickness, a function of cumulative temperature.

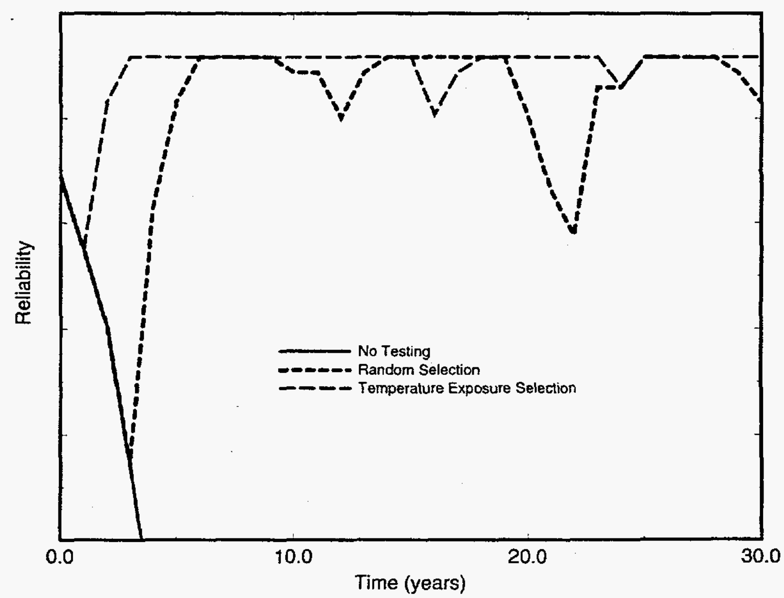

Figure 3. System reliability for different testing policies.

Conclusion

The ASSESS tool can integrate the work of modelers at many DOE facilities into a distributed framework that enables simulation of the DOE/NWC enterprise. The first phase of ASSESS includes weapon reliability equations, RoA databases, a Pantex process and scheduling model, a TSD model, and a neutron tube production model. ASSESS is designed to accommodate more data and models as they become available.