SIMULATION OF THE MRS RECEIVING AND HANDLING FACILITY

M. B. Triplett
C. H. Imhoff
C. J. Hostick
Pacific Northwest Laboratory
Richland, Washington 99352

ABSTRACT

Monitored retrievable storage (MRS) will be required to handle a large volume of spent fuel or high-level waste (HLW) in case of delays in repository deployment. The quantities of materials to be received and repackaged for storage far exceed existing waste management facilities capability to handle them. A computer simulation model of the MRS receiving and handling (R&H) facility has been constructed and used to evaluate design alternatives. Studies have identified processes or activities that may constrain throughput performance. The model also has helped to assess design tradeoffs such as those to be made among improved process times, redundant service lines, and improved component availability.

BACKGROUND AND OBJECTIVES

The primary mission of MRS is to provide backup storage of spent fuel or HLW in the event of delay in repository deployment. Therefore, the MRS facility must be capable of receiving spent fuel or HLW, possibly from 1800 to 3000 MTU per year, (metric tons of uranium) to relieve at-reactor storage constraints. This requirement places special demands on the general analysis and design of the MRS facility and particularly on its receiving and handling (R&H) facility. The facility design must assure that its annual throughput requirement is met. To do so requires handling of shipping casks, spent fuel assemblies, and/or HLW canisters at rates far beyond those of existing nuclear waste management facilities.

This paper describes a computer simulation model of the MRS R&H facility. The model is being used for the following activities:

- to assess the ability of the design to meet throughput and performance requirements (can the facility do what it is designed to do?)
- to identify the key processes, components, and parameters that determine facility performance (what are the major bottlenecks in the system)
- to provide an initial assessment of potentially important design tradeoffs (e.g., what is gained/lost by increasing redundancy?).

MODEL ASSUMPTIONS

The computer simulation model includes process steps associated with the R&H facility only and excludes steps associated with emplacement of storage canisters. The major assumptions used in these analyses are as follows:

- Process steps and parameter estimates were based upon a preconceptual design of the R&H facility.
- Process steps begin with shipping cask arrival to the MRS and end with welding of storage canisters containing consolidated spent fuel.
- The model included one hot cell designed to process spent fuel at a rate of 1800 MTU/year.
- The facility was assumed to operate three shifts per day, 7 days a week, 292 days a year.

The operations and equipment analyzed in this study do not exist in practice. Therefore, preliminary estimates were made of processing times and other operational features. The primary intent of this effort is not to develop definitive estimates for facility parameters but to use the available estimates to gain insight into the facility's overall performance. Using these insights, detailed design efforts can be more usefully focused upon the critical aspects of the facility.

The remainder of this paper describes typical selected results from these analyses for two portions of the facility: cask handling operations and assembly handling operations. Performance measures were developed for each and the effects of variations in the base assumptions were evaluated.

Model Structure

The computer-based simulation language selected to model the proposed MRS R&H facility is SLAM, which is an acronym for "simulation language for alternative modeling" (Pritsker 1979). SLAM is an advanced FORTRAN-based language that provides network symbols for developing graphical models that can be translated into input statements for direct computer processing.

Capabilities of SLAM

By modeling the R&H facility with the simulation language SLAM, the long-term operating performance of alternative facility designs were rapidly evaluated. SLAM enabled the project team to simulate the minute-by-minute operation of the R&H facility for time periods ranging from one to three years.

Definition of the Model Elements

The performance of an R&H facility depends on two key factors: 1) how proficiently a proposed facility handles and consolidates spent fuel assemblies, and 2) the ease of interaction between the proposed facility and the spent fuel transportation system. With these considerations in mind, the facility model was developed in module form. One module modeled the R&H shipping cask handling activities, and a second module represented the handling and consolidation of spent fuel assemblies.

Cask Handling Module. Cask handling refers to the receiving and unloading of shipping casks containing spent fuel assemblies at the MRS R&H facility. The analysis of shipping cask handling includes those operations from the shipping cask arriving at the receiving yard of the MRS facility to the unloaded cask being prepared for shipment out. Smooth functioning of these operations will facilitate MRS facility process operations by providing a steady flow of materials for storage and will help to ensure that the waste transportation system can operate smoothly without unnecessary delays in cask availability.

Cask handling operations within the R&H facility will also influence waste transportation system costs. In particular, the size of the shipping cask fleet will be influenced by the time that each cask spends at the MRS facility. If casks are delayed two, three or more weeks at the MRS facility, transportation system costs will be increased because the cask fleet required to handle a given quantity of spent fuel will be larger (i.e., more shipping casks will be tired up in the system), and longer turnaround times for casks will lead to higher shipping charges per shipment. Thus, cask handling operations should be designed to provide adequate storage for arriving casks, to promptly process casks to minimize delays, and to provide a smooth supply of spent fuel assemblies, or other waste materials, for storage.

Shipping cask handling operations are shown in Figure 1. These operations begin with cask arrival to the washdown and inspection area. It is assumed that the washdown area can only wash and inspect one vehicle at a time. Once this activity is completed, one trackmobile is available to transport the shipping casks to the one available hot cell. Only one hot cell is assumed to be available for processing spent fuel assemblies to determine if that one will be adequate to meet the 1800 MTU/year throughput requirement. Once the processing capability of one hot cell has been determined, the assumption of 100% processing redundancy with a second hot cell can be verified.

The model assumes that both hot cell inlet ports are available for the unloading of shipping casks containing spent fuel assemblies, with one overhead assembly removal crane servicing both ports. Once unloaded, the casks are prepared for shipment out of the MRS facility.

The simulation model of cask handling activities provides a basis to evaluate a facility's performance under a wide range of cask handling scenarios. Of utmost importance is SLAM's ability to represent a variety of stochastic cask arrival distributions. By being able to represent random cask arrival patterns, the model is able to estimate the performance of the MRS R&H facility under stochastic operating conditions, which is difficult, if not impossible, to do deterministically.

Assembly Processing Module. The modeling element representing assembling processes includes those operations beginning with removing assemblies from the shipping casks and ending with placing consolidated fuel rods in the storage canisters.

Once the assemblies are removed from the shipping cask, they enter the hot cell of the MRS R&H facility via the hot cell inlet port. The spent fuel assemblies

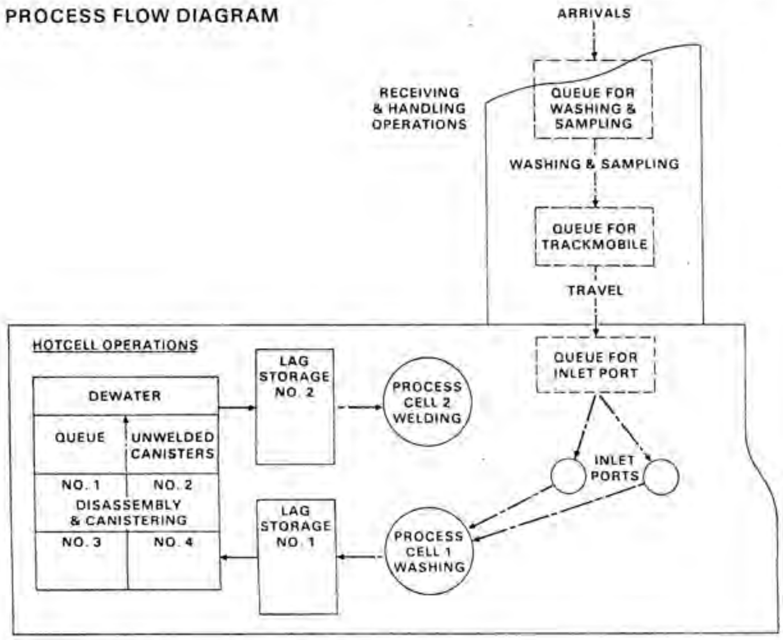

FIGURE 1. MRS R&H Process Flow Diagram

are then placed in a lag storage area before they are cooled down, chemically cleaned, and rinsed in a process cell. Following these operations, the spent fuel assemblies are transferred to a lag storage area that serves the disassembly/consolidation stations. After consolidation, the spent fuel is place in storage canisters that are welded and removed from the hot cell. These operations are represented in Figure 1.

Remotely operated devices will disassemble and consolidate the spent fuel assemblies within the confines of the hot cell. To meet the 1800 MTU/yr throughput requirement, 6480 assemblies will be processed. Assuming 292 work days per year, an average of 22 assemblies per day would be disassembled and consolidated. This rate far exceeds the capacity of any existing facilities that handle occasional small-scale consolidation activities.

ANALYSIS AND RESULTS

The simulation modules described in the previous discussion provides the framework for evaluating the expected performance of the waste handling facility and alternate performance scenarios. Because this application addresses new technologies for processes that have never been operated in high-production volume, the initial performance estimates of individual processes were treated parametrically. Therefore, the system performance was analyzed using 1) the estimated process times and 2) variations of the estimated process times. This analysis addressed the following goals:

- assess throughput performance
- identify key processes and components
- identify and assess design tradeoffs.

The first analysis step required that the initial estimates be used to identify the baseline system performance. The model results were based upon the initial design specifications for facility layout, process duration, and equipment reliability, and the final results indicated the general performance of the system. Included in the results was the performance of the individual process elements. This information indicated the process elements that had the greatest impact upon the performance of the entire system. The model was then used to examine these "critical" process elements in detail, altering the parameter estimates and determining ranges for these estimates that are required to meet the overall system requirements. Once the key process components had been identified, the tradeoff analysis of these key components began. Before these analyses were performed, however, criteria for making the comparisons were selected. These criteria are discussed below, followed by the results of the sample analyses.

Comparison Critieria - System Performance Measures

The primary measure of the system's effectiveness is the system's ability to meet the required production requirements. The model provides this information, yet many other additional performance measures are useful in evaluating system performance. The performance measures used in this analysis included process queue statistics and process utilization information.

Process queue statistics indicate system requirements for storage at each process step. These requirements include both the maximum amount of storage required, the average required storage, and the average time that items spent in queues waiting for processing at each process step.

Process utilization statistics indicate the percentage of time that machines were actually in use. Conversely, the amount of idle time is also calculated. High utilization indirectly indicates if the specific process is a constraint in the system and merits closer review. On the other hand, if utilization is low, the processing rates and machine reliability estimates are less critical to overall system performance.

The performance measures described above are applicable at both the overall system level and at the specific process level. The following discussions present some of the model results and indicate how these results were used to identify key system elements that merited closer evaluation in subsequent analyses.

Sample Analysis Results

The throughput time for spent fuel assemblies (time required for assemblies to enter the facility, be processed, and be cleared to leave the facility) was the primary performance measure for the entire system. Because of the uncertainty in equipment reliability at untried production levels, the ability of the initial design to meet the required annual demand of spent fuel assemblies was the primary question of the analysis. The model incorporated the stochastic nature of each process, and the resultant average throughput time was much greater than expected. Figure 2 displays the difference between the deterministic throughput time (the time required to process a single assembly assuming an empty and idle system) and the modeled time that incorporates stochastic effects. The dramatic increase in throughput time was due primarily to processing delays in the disassembly process. This unexpected result led to close examination of the individual processes to identify the source of the delays.

The performance of each major element of the system, displayed in Figure 3 indicated that the primary delay was the disassembly of the spent fuel assemblies. The average use of the disassembly machines was over 90%, and the average time that an assembly spent waiting for disassembly was over 40 hours. All other process elements had uses of less than 40% and waiting times in queue of less than 10 minutes. These initial results using the performance measures of throughput time, component use, and queue storage requirements provided quick insight into the capabilities of the system, indicating that the disassembly process to identify how variations in processing times, component availability, and component redundancy would affect the performance of the entire facility.

The network structure of the simulation model enabled simple modification of the disassembly process parameters to determine the sensitivity to variations. Experiments on the impact of 1) increasing the number of disassembly machines, 2) altering the processing time performance of each disassembly machine, and 3) the reliability of the disassembly machines were conducted to determine what levels of performance must be achieved in the design process to ensure that the facility meets its designed throughput goals. Figure 4 displays the effect that these experiments had upon the average system throughput time. The increased number of disassembly machines dramatically reduced throughput time until the time approached about 13 hours; at this point the other elements of the system became the constraints. The average processing times for disassembly also proved to have a significant impact upon system performance; slight deviations above the design estimates made meeting system requirements impossible and indicated the importance of developing accurate estimates of the processing times for the disassembly process.

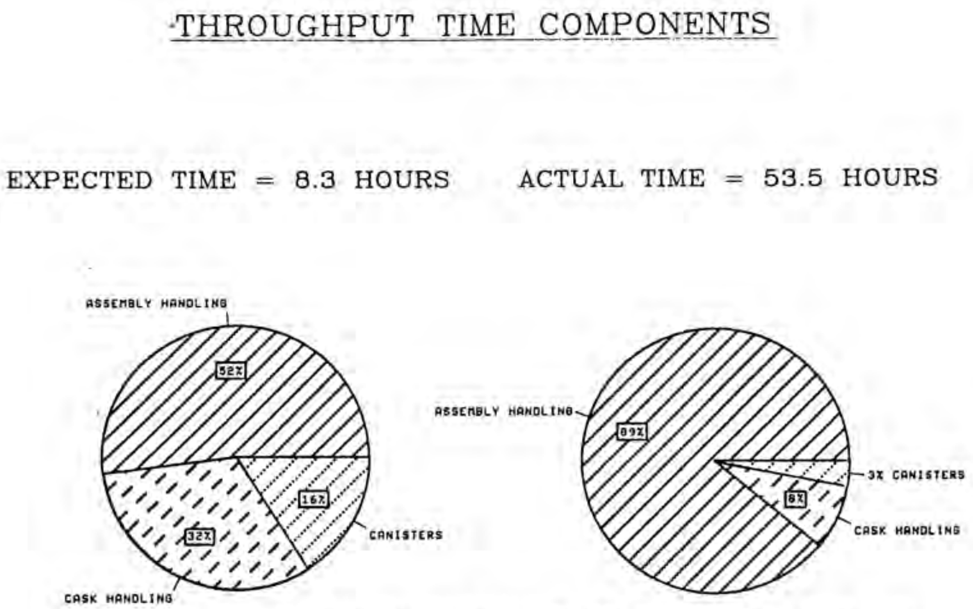

FIGURE 2. Deterministic Vs. Stochastic MRS R&H Facility Throughput Time

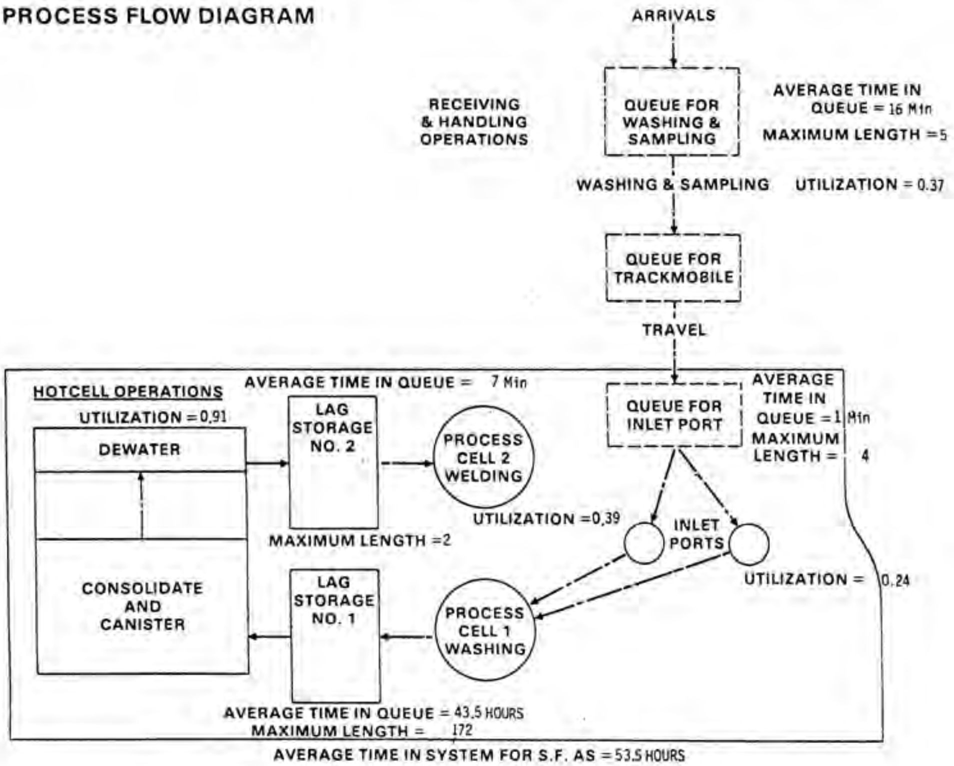

FIGURE 3. MRS R&H Facility Steady-State Performance

The impact of disassembly machine reliability also proved to have a dramatic impact upon system performance. Figure 5 displays the average throughput times for 4, 5, and 6 machines operating at different levels of reliability. The results indicate the dramatic decrease of the level of required reliability as more machines are added to operate in parallel. For example, the performance of 4 machines operating at 100% reliability is matched by 5 machines operating at only 80% reliability and 6 machines operating at 65%. This provides important insight into options for system performance in the design stage, particularly when the machines have never been tested at the high production rates that are required for this facility. These results indicate the need for a tradeoff analysis between design for machine reliability and the addition of more machines.

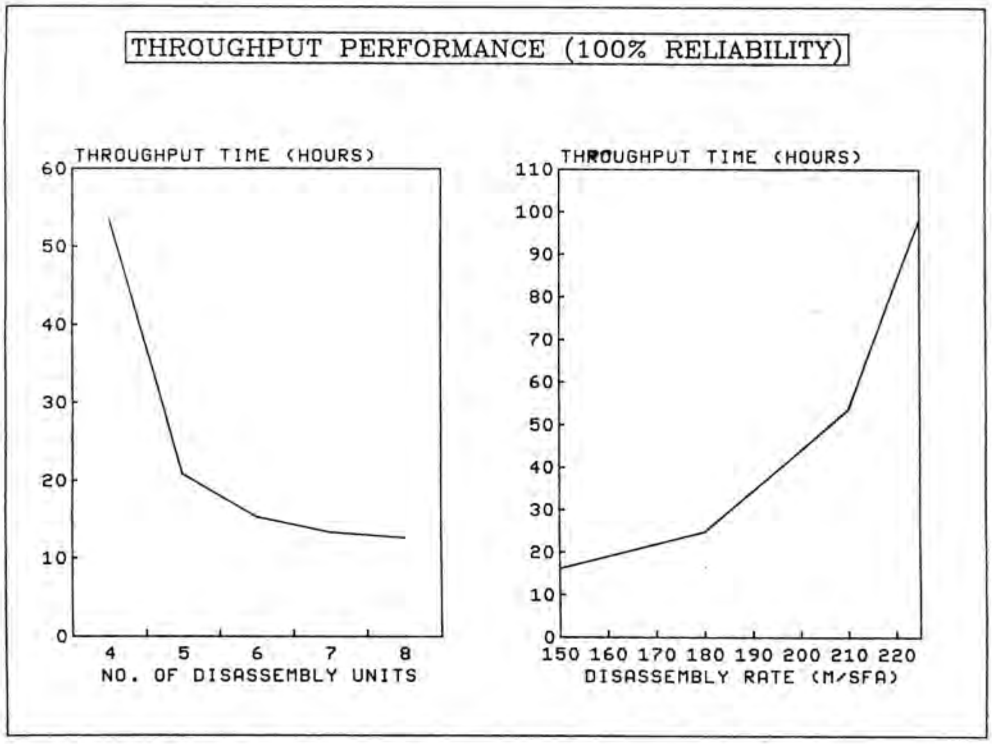

FIGURE 4. Variation in Disassembly Vs. Throughput Performance

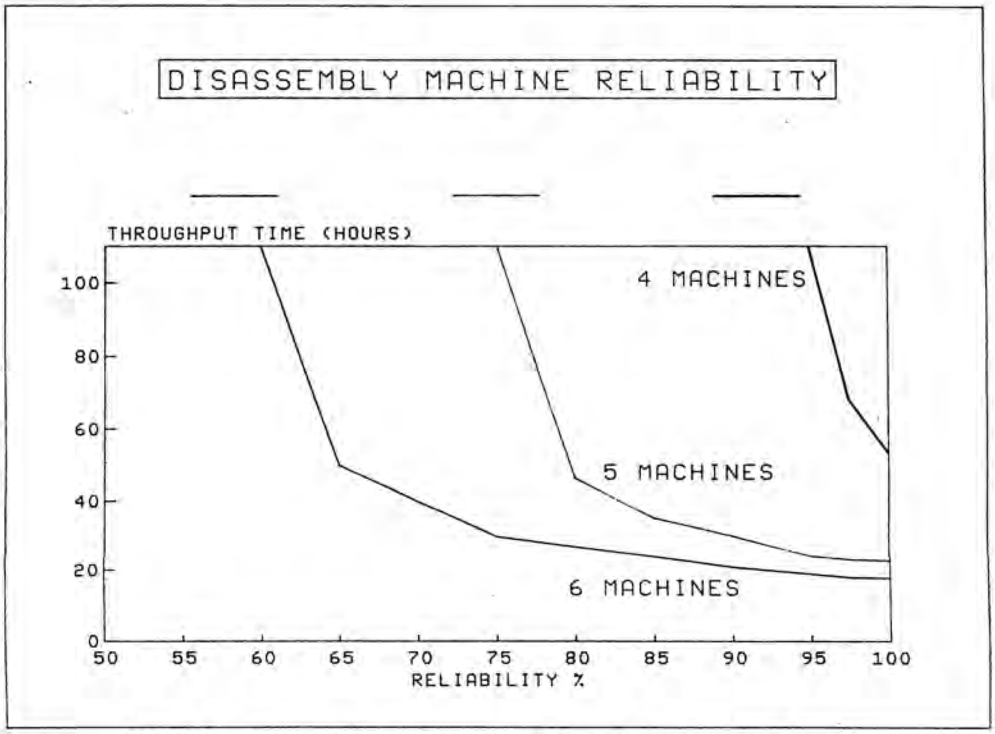

FIGURE 5. Disassembly Machine Reliability Vs. Throughput Time

SUMMARY

The design of facilities to routinely receive and repackage spent nuclear fuel or high-level waste from reprocessing will be increasingly important as plans proceed for deployment of repositories and temporary surface storage facilities such as monitored retrievable storage. Such facilities will have to provide assurances of being able to process the required quantities of materials. The simulation model of the MRS R&H facility has provided a useful means of analyzing the likely operational characteristics of the facility. These analyses emphasize the importance of taking a simulation approach. This simulation model gives designers a way of investigating the behavior of the system under actual operating conditions, including the effects of variations in arrival patterns of shipping casks, processing times and component availabilities. The extrapolation of spent fuel and waste handling facilities from infrequent or occasional operations to high production or routine handling of a large volume of materials necessitates the kind of analysis provided by simulation.

REFERENCES

Pritsker, A. B. and C. D. Pegden. 1979. Introduction to Simulation and Slam. Halstead Press, New York.