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SIMULATION OF WASTE PROCESSING, TRANSPORTATION, AND DISPOSAL OPERATIONS

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ABSTRACT

In response to the accelerated cleanup goals of the Department of Energy, Sandia National Laboratory (Sandia) has developed and utilized a number of simulation models to represent the processing, transportation, and disposal of radioactive waste. Sandia, in conjunction with Simulation Dynamics, has developed a Supply Chain model of the cradle to grave management of radioactive waste. Sandia has used this model to assist the Department of Energy in developing a cost effective, regulatory compliant and efficient approach to dispose of waste from 25 sites across the country over the next 35 years.

1 INTRODUCTION

Since the 1940's, radioactive waste has been generated and stored at more than 25 facilities across the United States. Within the last decade, the Department of Energy (DOE) has initiated ten-year mission to clean-up these facilities and permanently dispose of radioactive waste in the Waste Isolation Pilot Plant (WIPP). WIPP began receiving waste in 1999 and is scheduled to operate for 35 years.

Sandia, in support of DOE, has developed and used simulation modeling to analyze the processing, transportation and disposal of waste. Sandia's modeling activities began in 1995 by developing a series of discrete event models to evaluate the impacts of limited transportation resources and the logistics of transporting waste from 25 sites across the country. In 1996, DOE initiated a ten-year plan, which called for the clean up and disposal of waste at these facilities.

Over the 35-year period of WIPP, 6.2 million cubic feet or approximately 845,000 drums of waste will be disposed. Waste is shipped in specially designed shipping containers called TRUPACT-IIs. Three TRUPACT-IIs can be transported in a shipment. The capacity of a TRUPACT-II is fourteen drums. WIPP projects to accept as many as 37,000 shipments over the next 35 years.

The capacity of WIPP's waste transportation and disposal operations started at a rate of 5 shipments per week and will climb to 17 shipments per week over the next few years. Several of the storage facilities have processes in place to prepare waste for shipment. But many more require the construction of new facilities and regulatory approval to begin processing waste for shipment. Waste containers undergo various non-destructive testing and characterization in preparation for shipments. Figure 1 depicts the typical flow diagram of waste though these characterization steps.

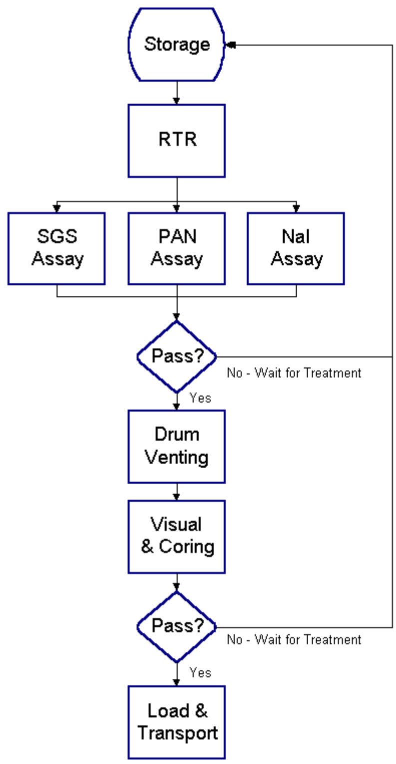

Figure 1: Flow Diagram of Waste Processing

The following is a description of the primary characterization steps:

1. Non-Destructive Examination through real-time radiography or RTR
2. Non-Destructive Radio-Assay through:
   - Segmented Gamma-Ray Spectroscopy or SGS
   - Passive/Active Neutron Coincidence Counter or PAN
   - Sodium Iodine scintillation Detectors or NaI
3. Drum Venting and Headspace Gas Analysis for Volatile Organic Compounds
4. Visual Examination
5. Coring and Analysis for RCRA Hazardous Wastes.

As might be imagined, the discrete event models grew to gigantic proportions, with as many as 30,000 simulation objects and a model runtime of 20 hours. Due to the large number of items being modeled, Sandia chose to employ a method of aggregation, wherein one item in the simulation may represent as many as one hundred drums. This proved to be somewhat inaccurate but allowed Sandia to decrease the model runtime to 8 hours.

The resulting data from the simulation proved extremely useful in documenting and analyzing scenarios. Sandia has used the model to analyze dozens of scenarios. However, for the model to be used more effectively and to analyze scenarios in a more timely manner, Sandia re-evaluated of the simulation approach. Changes needed to be made to affect the following factors:

1. Lengthy model run time
2. Ability to get data into and out of the model
3. Extracting relevant data into reports
4. Inaccuracy of aggregation
5. Need for increased level of detail.

2 OVERVIEW OF THE TRU WASTE SYSTEM MODEL

The purpose of the TRU Waste System Model is to provide a tool for ongoing study and analysis of the processing, transportation, and disposal of radioactive waste at WIPP. Some of the requirements of the simulation tool were as follows:

1. Encompass all the elements of the previous models
2. Allow for easy user modification
3. Allow for easy user understanding
4. Decrease model run time
5. Eliminate the need for aggregation
6. Increase the level of detail
7. Incorporate various alternatives for transportation
8. Automatically generate reports.

The simulation was built using Extend™, SDI Industry® Pro, and SDI Supply Chain Builder because of the flexibility required to achieve the above listed requirements (Rivera and Siprelle).

The benefit of this effort is to provide an inexpensive and easy to use tool that permits unrestricted and frequent evaluation and analysis of new transportation options and the logistics of waste transport from many sites. The model user is able to review information describing the behavior of the model both while the model runs and after the run is complete.

3 BUILDING THE MODEL

The structure of the model is hierarchical in nature. The model design permits the user to easily modify and build complex scenarios in a logical manner. The user may observe the model interaction at various levels. Figure 2 shows the top level of the model, which illustrates waste shipments moving from various storage facilities to the disposal facility. Each facility node or h-block on the top level of the model can be opened, to display the detailed level down to the drum movement through various processing steps, drums being loading into containers, onto trailers, and trucks.

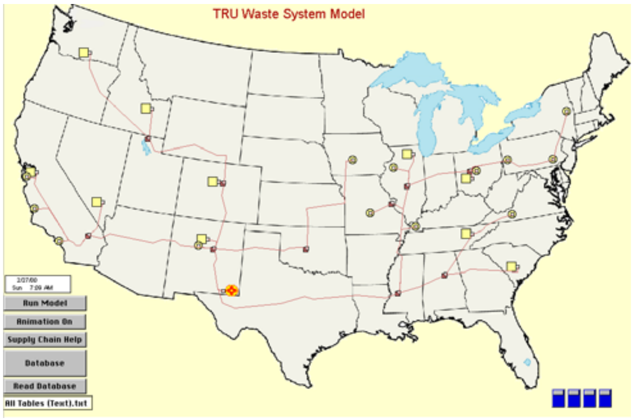

Figure 2: TRU Waste System Model Overview

The Database Manager stores scenario details and reference data that is used during the model run. The database is embedded in the model, but originates in Microsoft Excel™ or other database or spreadsheet type software capable of outputting tab delimited ASCII files. Database information is read into the model from the text file and converted into "Fast Arrays" for high-speed access and use throughout the model run. This eliminates unnecessary disk references resulting in optimized model runtime. Figure 3 shows the table format of the database manager.

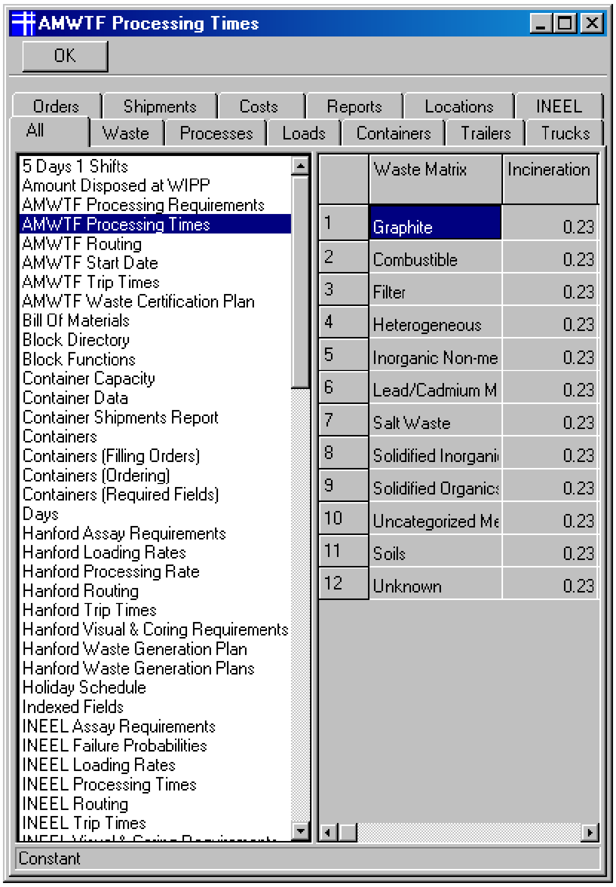

Figure 3: Format of the Database Manager

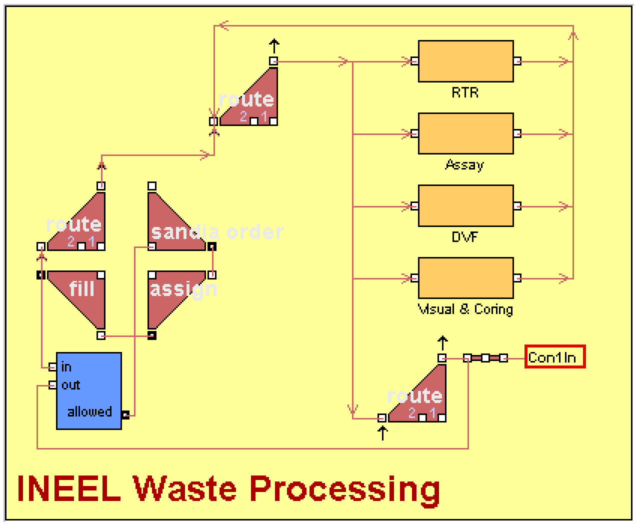

Figure 4: Waste Processing Stations

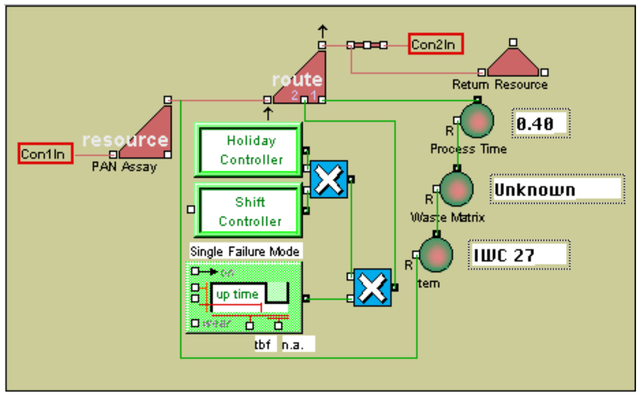

Figure 5: Detail of Processing Station

Basic Model Elements: There are five primary elements in the model:

1. Waste Categories - the model is fundamentally about the processing, transport, and disposal of various types or categories of waste. There are approximately 1700 waste categories defined in the model. Various tables in the database describe characteristics of these waste types - container type, material characteristic, weight, form, priority, and inventory.
2. Waste Processing and Loading Facilities - the model of the waste facility is comprised of various processing and loading stations. These stations are treated as resources available during specified times during the simulation. Figure 4 shows an example of the processing station resources as depicted in the model.

   The number of resources can be increased or decreased and controlled by increasing or decreasing the time available. Figure 5 illustrates how a shift controller controls the availability, holiday controller, and equipment controller for random failures.
3. Shipping Containers - the database contains information about shipping container capacity and the number of shipping containers per truckload for a given waste category both in terms of volume and weight. The model determines the actual capacity of a given shipping container. The database also contains data as to the fleet size and the utilization of containers. Figure 6 illustrates the "Russian doll" approach of how waste containers are assembled into loads, then placed in shipping containers, loaded onto trailers and then onto trucks for shipment to the disposal facility.
4. Vehicles - fleet size, truck and trailer properties (such as speed, load capacity, maintenance schedules, and random failure distributions) are also defined in the database.

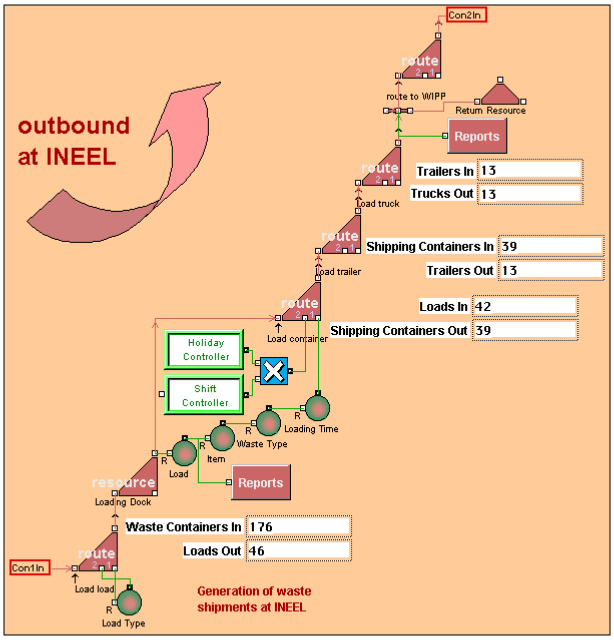

Figure 6: Waste Container Loading for Shipment

5. Routing Junctions - the model represents in a graphical format the highway and interstate routing that will be used to transport waste from a storage facility to the disposal facility. Each site has tables defining the routing and trip time to travel between the storage facility and the disposal facility. The model also allows for shipment of waste between sites as needed.

4 VERIFICATION AND VALIDATION

Sandia has collected the data from subject matter experts over the last several years. Data is reviewed and validated by both the storage facility personnel and the disposal facility personnel before it is used in the model.

Model performance has been validated through a series of time tested, foolproof approaches, where fully documented test situations are setup and run. The model output is then compared with the verified correct results and model analysis and adjustments are made to ensure reliable and accepted operation. In addition, Sandia has performed hand analysis of the test situation thus further verifying the accuracy of the results.

5 SCENARIOS AND MODELING RESULTS

Sandia has used the modeling approach described above to evaluate various alternatives. Many of the alternatives are defined and modified only in the database. This flexibility allows the user to read in a new database, run a scenario, and get results very quickly. Very few scenarios require modifications to the model itself. However, when these modifications are necessary, the user can quickly and easily make changes to the model due to the flexibility of the modeling approach and the model's hierarchical nature. The following is a partial list of some of the alternatives that have been evaluated:

1. Mobile waste characterization
2. Centralized characterization
3. Transportation fleet size alternatives
4. Drag and drop for container loading
5. Repackaging versus treatment
6. Modified site compliance milestones
7. Accelerated clean-up
8. Increased site processing capability
9. Increased disposal capability
10. Modified facility construction schedules
11. Multi-shift operations
12. Reduced processing requirements
13. Alternative storage site prioritization schemes
14. Delayed/accelerated fleet size modifications.

The results of any given scenario are compared to the program objectives and goals of the WIPP mission:

1. Regulatory compliance with site milestones
2. Risk reduction
3. Mortgage reduction
4. Effective disposal facility utilization
5. Maximize disposal by 2006.

The model confirms that all but two of the existing 25 waste storage sites can process, transport, and dispose of waste within the ten year period required by DOE. The model also predicts that the transportation and disposal facility will have extra capacity starting at year 11 and continuing through year 35. In the near term, the constraint is the storage facility's ability to process waste and the limited transportation fleet size. The model also predicts missed compliance milestones if increases to the transportation fleet are delayed significantly or if there are significant delays in the construction of new processing facilities. The commitment to early investment also increases the waste handling utilization of the disposal facility from 65% to 96%.

6 CONCLUSION

The supply chain model of the TRU Waste System has met and exceeds the requirements identified for the revision. It is a more accurate representation of the real system. It calls for no aggregation, the unit of the model is individual containers. Through the database, Sandia can now define the waste inventory in much more detail. The model is extremely flexible in terms of the user ability to make changes for scenarios and is easily understood. The model generates dozens of reports automatically and runs in less than an hour.

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