Savannah River Site HB-Line Plutonium Oxide Production Process Simulation Model - 17458

Nick Drucker*, Russ Shaffer*, Stefani Werner*
*Newport News Shipbuilding, A Division of Huntington Ingalls Industries
2401 West Ave.,Newport News, VA 23607 (David.N.Drucker@hii-nns.com, William.R.Shaffer@hii-nns.com, Stefani.L.Werner@hii-nns.com)

ABSTRACT

The AFS II/Plutonium Oxide Production process is in its initial operational phase at the Savannah River Site's (SRS) HB-Line. The process is new for the facility where it is being performed, but the facility itself has been in use on and off for over 50 years. Beginning this process inside the facility has resulted in multiple process delays, due to both equipment issues and process restrictions. In order to better understand the process and to identify ways to improve facility performance, Savannah River Nuclear Solutions (SRNS), in conjuncture with Newport News Shipbuilding (NNS), developed the HB-Line Process Simulation Model. This tool completely replicates the operations that comprise the HB-Line process and simulates all of the constraints associated with the process. The model realistically accounts for the number of personnel required for a process step, the time required for a process step to occur, rules related to the parallel operation of process steps, and realistic equipment and operational delay data. The result is a tool that allows SRNS to test different scenarios for improving the process throughput, while realistically accounting for potential process delays and restrictions. The tool is currently in use and has allowed SRNS to present to their customer, the National Nuclear Security Administration (NNSA), estimated production capabilities over wide-ranging timetables and assumptions.

INTRODUCTION

The Savannah River Site's (SRS) HB-Line is located on top of H-Canyon and is the only chemical processing facility of its kind in the Department of Energy (DOE) Complex[1]. The facility was built in the early 1980s to support the production of plutonium-238 (Pu-238), which is a power source for the nation's deep space exploration program, and to recover legacy materials stored in H-Canyon[2].

The HB-Line Facility recently started up the production of Plutonium Oxide, which is the feed material for the Mixed Oxide Facility (MOF), in an effort to reduce legacy nuclear material inventories. This chemical separation method is a complex and unique process. In order to better understand the process and to identify ways to improve facility performance, Savannah River Nuclear Solutions (SRNS), in conjuncture with Modeling and Simulation (M&S) professionals from Newport News

[1] "Savannah River Site Facts: HB Line", Savannah River Site Website, http://www.srs.gov/general/news/factsheets/esrs_hb.pdf
[2] Ibid.

Shipbuilding (NNS), developed a Chemical Separation Process Simulation Model. This tool completely replicates the operations that comprise the process and simulates all of the constraints associated with the process. The goal of the model was to allow SRNS to more accurately understand the capacity of the HB-Line process and determine whether the facility could meet DOE production agreements.

The SRNS and NNS team developed a discrete event simulation model to replicate the HB-Line process. The model includes visual representations of the process steps, as well as visual indicators of process step activity. In addition, the model utilizes a database for the collection and storage of simulation run information. From this database, the tool automatically generates charts relaying information about facility throughput, personnel utilization, equipment utilization, and process down times. The complete system then allowed SRNS to validate that the process simulation was accurately reflecting the HB-Line processes and to relay to the NNSA how the system was performing. The resultant data allowed SRNS to test a variety of scenarios in the simulation and compare outcomes to determine how different configurations, equipment failure rates, personnel groupings, and facility shutdowns would impact overall production rates. SRNS then presented these findings to the NNSA and continues to utilize the model to this day to forecast production rates and analyze how actual facility performance to date may impact future production.

DESCRIPTION

The HB-Line Plutonium Oxide Production process is a complex chemical separation activity. As such, multiple pieces of key equipment are vital to the performance of the operation. Additionally, ensuring properly trained individuals are on hand to oversee the process requires balancing the workforce available to avoid over-allocating resources or starving the processes of key individuals. The facility has been supporting its current mission since 2014. A chemical processing facility such as this one presents unique challenges such as equipment failures, facility shutdowns, lack of personnel, and general safety constraints. An analysis of the challenges faced by the HB-Line production team led SRNS to engage with NNS M&S professionals to determine if the expansion of an existing SRNL model of the Plutonium Oxide Production process would be beneficial. NNS's analysis of the existing process revealed that an enhanced model could generate the following benefits:

- Visual representations of the HB-Line and the Plutonium Oxide Production process to engage stakeholders and allow SRNS to understand potential bottlenecks in the process.
- Utilization of NNS's in-house simulation engine to provide more control over detailed processes and variables.
- Automated output charts would allow SRNS personnel to own and operate the simulation without needing to be M&S experts.

The NNS team worked with personnel from SRNS and SRNL over a period of six months to develop the resultant HB-Line Plutonium Oxide Production process simulation model. The simulation model is comprised of all of the process steps performed to support the Plutonium Oxide Production process at the HB-Line and H-Canyon. In order to create a manageable scope for the project, the simulation utilizes input data and constraint assumptions to account for processes that occur outside of the immediate HB-Line area that could impact the process, e.g. availability of material to process.

The model also provides SRNS with the ability to control multiple variables in the process to perform experiments on facility operations. The variables of concern in the HB-Line simulation pertain to the utilization of equipment, personnel requirements, safety restrictions, and shutdowns. This process simulation captures the interaction of these variables to determine facility throughput and provide an experimentation platform to test how different personnel configurations, safety restriction changes, and equipment failures/off-line time impact throughput.

Modeling Facility Utilization

To develop the HB-Line process simulation, NNS engaged with SRNL to enhance an existing HB-Line process simulation and employed their proprietary Common Simulation Framework (CSF). The CSF is a flexible discrete event simulation engine that allows M&S experts complete access to the entire simulation engine code. With this level of access to the underlying engine code, NNS teams are able to capture even the most complex processes in simulations, in a time-efficient manner, providing the level of detail required for complex simulations such as the HB-Line effort. The CSF also utilizes excel input sheets as a means for data entry to drive simulation runs. These input sheets ensure that upon model completion the system can be modified to support scenario evaluations and experimentation without the need to write CSF code to make changes.

The HB-Line model is cradle-to-grave and includes receipt of material to the line, the creation of product, and its transfer to storage. The simulation uses assumptions provided by SRNS process experts regarding the amount of material produced during each step of the process and any by-products. In this way, the model can be updated with new process step yields through input data, not through having to update inherent algorithms in the model. Additionally, the tool can be updated to reflect changes in the process chemistry, e.g. one step is modified to generate a lower percent of material loss, in the case that yields change as the SRNS team runs the process over time. The NNS and SRNS team determined this to be the best path to ensure the model could instead allow for the SRNS team to focus on process bottlenecks not pertaining to the chemistry of the system.

Following the initial input of material into the system, the HB-Line model captures the steps to process this material (as a liquid) through multiple refinement steps to extract the target materials. Each process step has an allocated time distribution to ensure variability is captured, resource requirements, and a distribution for equipment failure likelihood. In addition as discussed above, the process yield is determined through input, but does have a distribution associated (e.g. to account for a loss percentages for example). Additionally, the model captures both planned and unplanned facility shutdowns. The SRNS team developed a list of planned facility down time to accommodate events from training evolutions through planned loss of steam access. In addition, the SRNS team developed a list of potential unplanned shutdowns (e.g. safety pause) and allocated time distributions for the length of the shutdown and a percent chance of occurrence.

To account for the personnel requirements the model included input about the types of roles personnel fulfill during operation, the number of qualified and available workers for each role, and worker shifts. The SRNS team is then able to experiment with training more personnel to fill positions on a shift and determine its impact. Additionally, the model supports determining which roles may be under or over-utilized to allow for a more balanced staffing plan.

Verification and Validation (V&V)

Following the completion of the model, the NNS, SRNS, and SRNL team engaged in extensive verification and validation of the tool. The V&V process ensures that the model output is reliable, based on historical data and subject matter expert (SME) input. During the creation of the tool, NNS often presented data to SRNS for review to ensure the model logic was sound. This verification ensured that as the model was constructed, it was not built on faulty assumptions that could have unforeseen consequences on the output.

The verification processes involved both visual inspection of the model graphics (figure 1 below) as well as review of the data produced by the system. The model visuals allowed the SRNS and SRNL teams to watch a single run of the simulation to ensure no processes occurred out of order, that no processes occurred in parallel which were not designed to be run that way, and that the flow of material was correct.

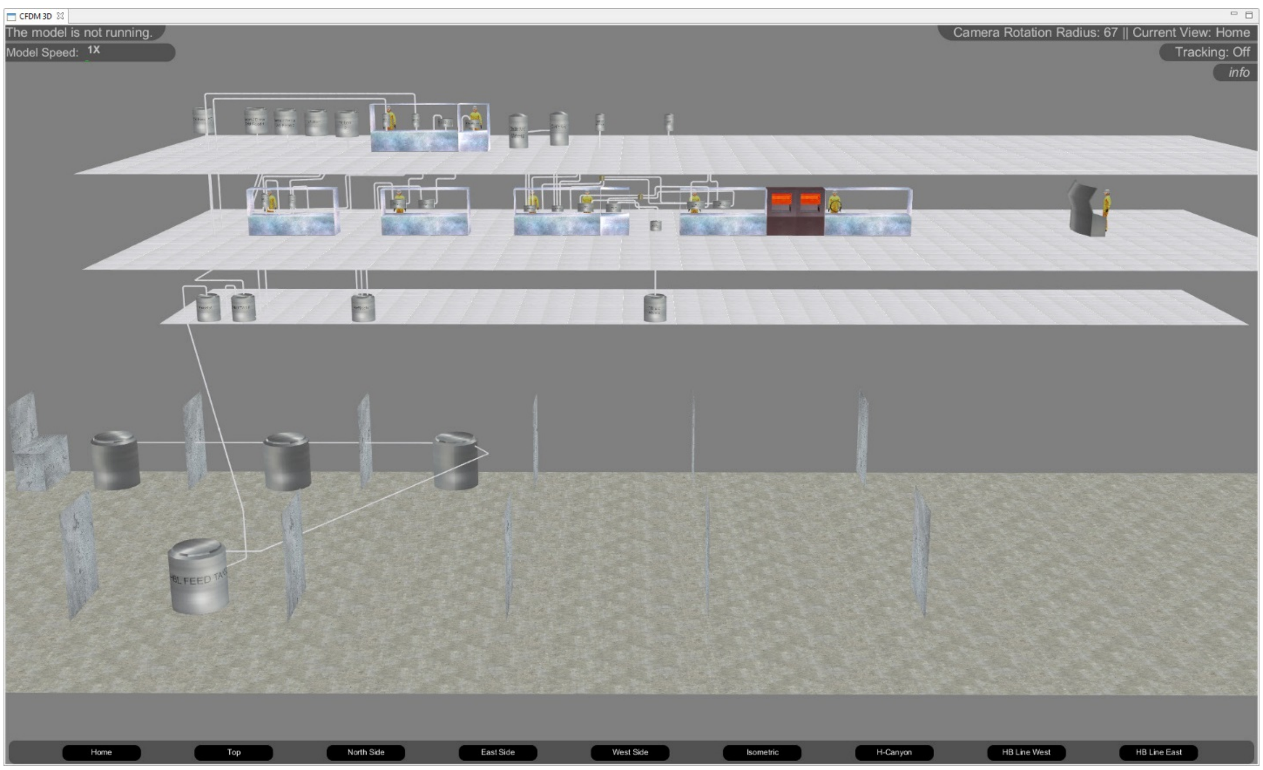

Fig. 1. HB-Line Model Graphics.

Following visual verification that the process was occurring properly, the team began verification through output data. While the visuals allowed for an inspection of a single run to ensure the model was behaving as expected, the data review allowed the team to perform multiple model runs and aggregate the data as they would for a scenario analysis and further review to ensure the model continued to perform as expected. The data review occurred over multiple weeks with the NNS, SRNS, and SNRL team reviewing chunks of the process individually, rather than trying to verify the entire process at once.

Once the team completed the verification process, NNS provided an individual on-site to facilitate validation of the simulation data. The validation process ensures that the model produces data that is expected and/or in line with historical data. Validation follows verification to ensure the model behavior is correct prior to experimenting with model input data. The validation of the HB-Line tool took several weeks and involved multiple runs with actual (i.e. real system) input data. Due to the sensitive nature of some of the information required in the model to produce reliable data, the simulation was only run on-site at SRS with this information. Following the validation process, the SRNS team determined the model was producing expected results and accurately captured the entire HB-Line process. At this point, the model was deemed fit for use in experimentation to test the facility capacity and throughput.

DISCUSSION

The result of this effort was a tool that allows SRNS to test different scenarios for improving the process throughput while realistically accounting for potential process delays and restrictions. Use of this simulation model allowed SRNS to present to their customer, the National Nuclear Security Administration (NNSA), the true capacity of the facility performing the operations. This was accomplished without needing to perform several years of facility runs to generate this data. The model continues to support SRNS in their management of the HB-Line and data continues to be provided to the NNSA.

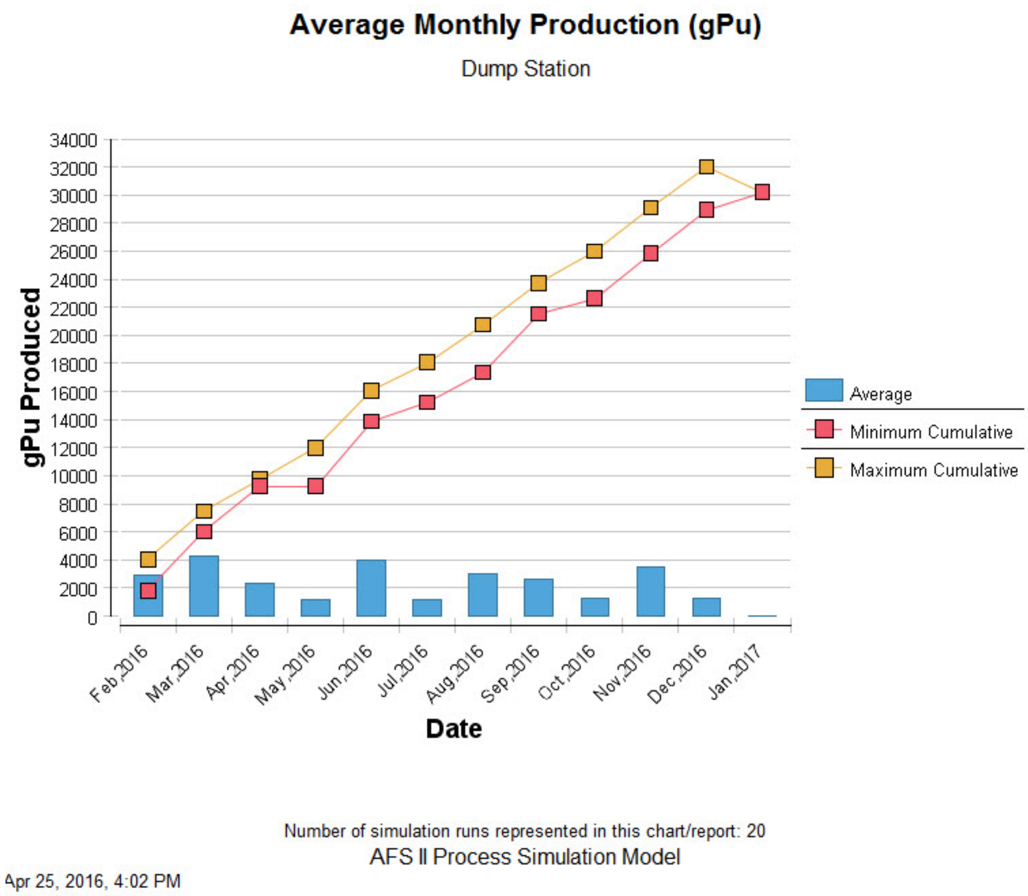

Fig. 2. Example output chart. (SIMULATED DATA ONLY)

Figure 2 shows a sample (notional data) of the type of data the model produces to facilitate experimentation. This chart demonstrates how the model can generate data about throughput of different process locations. The multiple simulation runs produce the variability that allows for analysis of likely outcomes, displayed here as a minimum and maximum cumulative production rates, as well as the average monthly production (blue bars). Such charts allow the SRNS team to determine where bottlenecks may exist; in this example, July production drops significantly from June before rebounding. The team is then able to examine other output charts about that month to determine if the drop in production was the result of a planned event, some unplanned event, or a bottleneck in the system.

All charts from the system are auto-generated following a batch of simulation runs. This reduces the requirement for SRNS personnel or analysts to perform post processing of the data. The charts are designed to relay information quickly to decision-makers so that they can effectively understand the processes. Additionally, the charts provide a medium for presenting information to stakeholders about the production process. Aside from the shown production rate chart, other charts generated by the model include:

- Process step Gantt charts
- Facility shutdown Gantt charts (planned and unplanned)
- Resource utilization charts

Benefits

The use of the HB-Line model by SRNS helped to reveal the true facility capacities well in advance of discovering them through actual runs. This allowed the NNSA and SRNS to make decisions about the future production at the facility, with trusted data, several years earlier than otherwise would have been possible. The extensive V&V of the model allowed SRNS to confidently present the findings to the NNSA and facilitate a discussion about the facility's production going forward.

In addition to the identification of throughput early in the facility's lifecycle, the tool continues to provide an experimental platform to refine and improve processes during facility ramp up. The tool is supporting experiments to determine how process changes may impact the ability of the facility to reach a steady rate of production as efficiently as possible. In addition as SRNS continues to build up its trained workforce, the model is allowing them to determine how to best deploy these resources across shifts to support production.

Future Planning

As the HB-Line continues to operate and process material the model will continue to support planning of facility upkeep. One of the challenges for the facility is working around planned shutdowns. The simulation allows SRNS production teams to input these schedules into the simulation to determine the ideal time to perform these operations. In addition, the tool can support in the event of an unplanned shutdown. The tool also allows users to feed in information about unplanned events to project future production based on an event that has just occurred unexpectedly.

Outside of facility down time, the tool also continues to support planning for future production rates. As HB-Line continues to operate and more data becomes available, the tool is updated with the real world results and can continue to support future projections. Additionally as the facility team experiments with process efficiencies, material movement rates, and other facility restrictions, the tool will continue to allow them to reflect these changes' effect on production.

A final area where the tool will continue to support SRNS into the future is in planning for capital expenditures. Given the age of the facility and the nature of the Plutonium Oxide Production process, there are potential opportunities to invest in capital improvements. However, weighing the value of any capital expense compared to its impact is still necessary to avoid expenses that do not have large enough effects. The model will allow SRNS to weigh the cost versus benefit of these potential expenses to determine their true value. For instance, if the facility experiences problems with a pump system and the team wishes to determine if purchasing a new pump would allow the process to occur more efficiently or reduce down times, they can test the expected changes from the new pump in the model and compare the cost to the changes in production rates.

CONCLUSIONS

The creation and use of the HB-Line process model allowed SRNS to perform multiple scenario experiments over a short period of time, determining the throughput capabilities for the facility in a controlled cost and time-efficient manner. The tool continues to support SRNS as they run the HB-Line, while providing a platform for experimentation and discussion with the NNSA about the facility's future production.

Additionally, the model design is allowing SRNS to operate and maintain the model without continued support from a team of M&S professionals. This flexibility is ensuring the continued cost-efficiency of the model. The results of the model have also led SRNS to investigate several other processes at the site through simulation. These efforts will continue to expand the capability of SRNS to efficiently and effectively monitor and improve some of their complex processes on-site, leveraging the latest technology to generate reliable results.

REFERENCES

1. "Savannah River Site Facts: HB Line", obtained from Savannah River Site website, http://www.srs.gov/general/news/factsheets/esrs_hb.pdf

ACKNOWLEDGEMENTS

The authors would like to thank the entire SRNS team who supported the creation and utilization of this model. Specifically Nick Miller, Brian Pool, Glenn Morgan, Lee Sims, Robert Entzminger, Tim Worth, and Lance Traver who dedicated much of their time to supporting the process. The team would also like to thank Mark Jones of SRNL for his support and expertise throughout the project. Without their support the effort would not have been successful.