Results of Modeling and Simulation Support to Specia Nuclear Material Handling Facility Operations – 16053

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ABSTRACT

Newport News Shipbuilding (NNS) is the sole designer and provider of nuclear powered aircraft carriers and one of only two companies in the United States to build nuclear powered submarines. As part of the upkeep of aircraft carriers, the ships return to NNS once in their lifetime for a complex overhaul and to be refueled. In support of overhaul operations NNS maintains a state of the art Special Nuclear Material (SNM) handling facility. Due to the complex nature of the operations that occur within this facility, during the design and initial operation of the building NNS developed a facility simulation model to provide decision support during the project planning and operational phases. This tool allows users to experiment with process times, process order, equipment utilization, personnel utilization and spatial utilization. By capturing the planned operations, time distributions for operations, equipment sizes and uses and personnel requirements, the tool accurately reflects the planned use of the facility. This realism allows the user to experiment with any aspect of the facility, in a controlled and cost effective space, and determine how changes or potential delays may impact overall facility operations. Thus the model allows for rapid exploration of multiple scenarios to determine likely outcomes, allowing a user to identify risks well ahead of their realization and explore mitigation strategies in a controlled space, to determine the ideal path forward.

The tool was successful during the initial operation of the facility in helping to identify and mitigate risks related to the complex operations occurring during SNM handling. The tool is now in use to support planning for the next series of operations that will occur within the facility. The initial operations the model supported occurred during the deactivation of the USS Enterprise, and future operation will focus on the overhaul of Nimitz class aircraft carriers. The NNS planning team is currently using the tool to assess potential risks and challenges that are identified as potentially impacting the schedule and timelines for these overhaul processes. In addition, the NNS development team is working to add new operational steps to the model, capturing work that is occurring near the facility, but which directly impacts the facilities operational abilities. In conjuncture with the engineering planning division, the NNS development team has run over 20 complex scenarios through the tool. The team has provided output from these scenarios to both NNS personnel and government representatives. To date the model has successfully supported the identification of several feasible paths to incorporate new processes, dictated by the work to support a overhaul vs a deactivation. The model also provides a spatial arrangement component that allows users to experiment with different equipment placement within the facility.

Due to the fidelity of the model, arranging equipment with the spatial component allows a user to set up the facility in an experimental layout and run the processes inside the facility to determine if the layout will be feasible, or if it would impact operational capabilities. Additionally, the spatial component allows for visual collaboration between stakeholders to ensure all operational personnel are aware of the current and planned layout, and that they do not locate equipment or work stations in locations that would interfere with facility operations. The spatial component, in combination with the simulation component, has resulted in several documented improvements in process. These include: the identification of additional equipment which could be stored outside the facility, without impacting operations, to increase space; confirmation of the ideal placement of a large water tank; and identification of several risks related to planned equipment storage area, allowing the team to develop new plans and avoid realizing the risk.

INTRODUCTION

Initiating the use of a newly-constructed SNM handling facility, in a constrained space, presents unique challenges to ensuring safe and effective operations. Newport News Shipbuilding is currently operating the M-290 facility for the first time, with actual nuclear material. As the shipyard prepared for the facility to go operational, the company developed a set of analysis tools to help them optimize operations and identify risks prior to live execution. The shipyard maintains a robust modeling and simulation (M&S) capability, designed to address exactly the types of challenges expected when operating the M-290 for the first time. The company developed two tools to support analysis of the M-290 operations: a Spatial Arrangement Tool (SAT) for spatial analysis, and a facility process model to assess operational performance.

These tools were designed and constructed prior to M-290 live execution and currently support assessment of operational changes and potential challenges. To date, the tools have supported these process assessments by providing visual representations of the facility, allowing the production teams to identify potential space constraints. Concurrently, the simulation tool has allowed the teams to test strategies to set operational times, equipment needs, and crew sizes to the most efficient levels possible.

DESCRIPTION

The M&S discipline provides a suite of tools and techniques for the assessment of multiple problem spaces. The goal of M&S is to provide an experimental platform where users can test hypotheses about their area of interest in a controlled and cost efficient environment. M&S techniques have been applied to a wide variety of problem spaces, everywhere from questions of traffic flow to human behavior. Within NNS, M&S has grown to support assessments of potential risks during heavy manufacturing and material movements, specifically during the construction and overhaul of nuclear powered aircraft carriers and submarines. NNS has developed these capabilities over the last decade and a half, and maintains a large group of M&S experts tasked with developing solutions to some of the largest challenges faced by the shipyard. Currently, the NNS tools are being applied as a new SNM handling facility, the M-290, goes into its first use, to ensure the company continues to meet customer needs while maintaining a high level of safety.

Modeling Facility Utilization

The M-290 facility's initial use is occurring during the deactivation of the USS Enterprise. The shipyard is over 130 years old and contains multiple legacy facilities and equipment, making space a premium. The M-290 was constructed in a location where it could support the operational mission of transferring special nuclear materials (SNM) out of the shipyard. However, because of the other facilities located in the area that support the same mission, construction of the M-290 had to occur in a small space. To ensure that the limited space would not impact its performance capabilities, NNS developed the M&S tools described in this paper. During the planning efforts for this work the NNS team developed a discrete event simulation (DES) tool capable of capturing the planned process, as well as a spatial arrangement tool for analyzing the ideal location of large equipment in the constrained space within the facility.

The DES facility model captures the operations performed within the M-290 during SNM handling. The facility model covers operations associated with packing and shipout of SNM. In addition, the tool examines the operations occurring directly outside the facility where the casks initially arrive and eventually depart. To ensure these operations are accurately reflected in the model, process times for each step, required personnel, and any equipment needs are captured. Employing NNS's proprietary Common Simulation Framework (CSF), the model's flexible structure lends itself to rapid modification by non-technical users.

To ensure this capability, the models employ a set of outside input sheets which dictate everything from process steps and time distributions to manning levels and equipment needs. By placing the majority of the operational information in external locations, it is not necessary to have a detailed understanding of how to write computer code to make modifications to the process, making the model accessible to non-technical users. The external sheets allow anyone familiar with the process to make changes to the order of operations, add or remove steps, modify manning or equipment levels, and modify or experiment with the logic of step constraints within the model. The ability to quickly make modifications greatly increases the usefulness of the model when compared to traditional tools which potentially require hours to change similar components.

The model also employs an actuals input sheet which captures information about processes performed to date. Factoring this information into the model ensures that each time the system runs, it starts from the most recent point in time and moves forward. The actuals data also forms a basis for analysis and provides input for future planning of deactivation operations. By implementing the flexible nature of CSF, the team can capture the operational steps with a high level of detail, while ensuring accuracy to actual process steps and the creation of a dynamic experimental platform for rapidly assessing new plans.

The model's logic pertaining to spatial limitations and equipment utilization also ensures that the production team can accurately assess areas where their plans may encounter delays. An example of this occurred during the planning phase when the team was able to identify that operating only one of two cranes inside the facility when a cask was being loaded resulted in significant time delays. They were able to modify this plan well in advance of execution and further assess the new operations to ensure they did not create danger for the personnel within the facility.

The second component of the facility model is the Spatial Arrangement Tool (SAT). The SAT is a visual representation of the facility and its equipment, built to exact dimensions. NNS performed laser scans of the facility to generate point cloud data and guarantee accuracy of the dimensions used in the SAT. Point cloud data allows the software employed to determine the exact dimensions, locations, and sizes of the facility and its equipment. Using the data from the point cloud scans, the model is able to accurately reflect spatial constraints with incredible fidelity.

Using the point cloud data within the SAT, the production team is able to move objects around the environment and observe how they fit within the allowable space. The equipment of the greatest concern are racks for holding cask components and equipment required to work on the cask. Employing a drag and drop functionality, the SAT allows the user to place the objects in the facility, and highlights or disallows overlapping equipment (the user may choose whether to allow overlaps or not). Taking this technology beyond just spatial visualizations, the tool allows the user to plan where to place equipment and to model the current facility layouts. The SAT also serves as a front end for the facility model, allowing a user to move equipment around the SAT to reflect the exact facility layout on any given day and run the facility model with that setup. Utilizing this level of fidelity for current facility layouts increases the accuracy of the model data and helps the production team better identify constraints and limitations.

DISCUSSION

Within the M-290 facility, the model supports daily operations and the spatial arrangement component allows the production team to continually assess spatial constraints and identify potential future constraints well in advance of their occurrence. Using this tool, combined with the facility model, the team is constantly generating potential recovery paths to alleviate any delays that arise. The re-planning of work and development of mitigation strategies prior to a delay occurrence is resulting in reductions in risk to the overall program schedule.

Benefits

During a review of proposed new equipment utilization for the deactivation of the USS Enterprise, the M&S team noticed a conflict with the equipment placement. Initial plans called for a new stand to be located near one side of the facility for some operations and then to be moved to the opposite side during later steps. The model showed that based on the proposed location the production team would need to perform two crane lifts to move the stand from one end of the facility to the other. This added additional time and risk by introducing twice as much rigging and crane movement time. The team then worked with M-290 production to physically validate that the location of the stand would support operations. By identifying the added crane moves before operations began the model was able to help the production staff avoid unnecessary crane activity and potential delays to the schedule.

Throughout the same period, the M&S team examined how the process changes associated with the stand would impact facility operations. Because the changes involved added process steps the M-290 production staff identified a minimum of one additional working week in the schedule to support the operations. The M&S team was asked to examine whether the added time could be avoided through some mitigation strategy. The team used the process model to identify that an increased working crew for the new operations would eliminate the need for additional schedule time. They confirmed with the M-290 production crew that the staffing was available to support the added manning for the new steps, which solidified the feasibility of the model's prediction of no additional schedule time. Identification of the need for the additional crew to be available during the new steps, well in advance of execution, also allowed the M-290 production crew to ensure they trained and maintained enough staff to support the operation. In this instance, the use of the model resulted in avoiding the addition of working days to the schedule, which would have resulted in projected increases in cost.

When the M-290 facility was initially completed, the M&S team performed a study to identify the optimal number of equipment racks required for storing certain components. The racks are large and the initial plan to position four racks inside the facility meant a large amount of floor space would be sacrificed. The production team asked the M&S team to determine if it was possible to operate with less equipment while maintaining the same operational tempo. The team examined the M-290 process in the model, looking at the use of one to four racks. The results showed that the difference in operational performance between three and four racks was negligible. The experiments also showed that using two racks instead of three would result in some performance loss, but not to the extent assumed by the production team. Finally, the study showed that one rack was not feasible. The results of this work allowed the production team to suggest process changes to the customer, to operate with two or three racks, instead of four, freeing up more floor space and reducing safety risks to workers.

When assessing how the facility would perform following its completion, but prior to the first live runs, the facility model supported a study of the ideal number of locations in the facility that should be active at a given time. The initial plan called for half of the facility to support SNM transfers while the other half of the facility was staged and prepared for later use. The production team, working with the M&S team, examined whether reserving more space in the facility for live operations and holding less space for staging would be more effective. The assumption was preserving more space for live operations would increase efficiency. However, the model showed that the gains from using more space for active operations did not increase overall performance. Due to other limitations within the facility and the use of cranes, the plan to use half the facility at a time for active operations proved to be more efficient. The results of the study allowed the production team to avoid changes in the work plan and avoid schedule risks that could have arisen during the first active facility operation.

One of the longest running uses for the facility model and SAT has been in assessing how the facility can transition from supporting each new ship that comes to NNS for overhaul work. The tight space around the M-290 and its location near where aircraft carrier overhaul occurs means there is little time for turnaround of the facility between each ship that arrives at the yard. Specifically, when the facility transitions from work on the USS Enterprise to the USS George Washington there will be new equipment required, which has to be brought to the facility, and the personnel need to train to use the equipment. Ensuring these operations can occur without impacting the timelines for the USS Enterprise and USS George Washington require careful planning of both the facility and personnel.

The M-290 production team has been using the model to help them assess the best time to begin the movement of new equipment into the facility and when to start transitioning personnel to train for the next ship. The model has helped them test scenarios where they can slowly transition personnel off work on the USS Enterprise while also beginning to reserve space in the facility for new equipment, and has shown that the current proposed plan of transition will not impact the schedule for the USS Enterprise or the USS George Washington. The SAT is also supporting the production team in determining where to best position the new equipment as it arrives, ensuring it does not impact the work that will be concluding on the USS Enterprise. To date, the M&S team has examined multiple scenarios and has helped the production team down-select to the best possible transition plan, which has been presented to the customer.

While the transition from program to program is generally planned to occur smoothly, the nature of overhaul work often dictates changes in schedule once a ship has arrived. This is further compounded by uncertainty in funding from the Navy customer, which causes ship schedules to be less rigid than is ideal for planning. The facility simulation has supported several “worst case” scenario evaluations for the production team and the customer to assess how schedule changes due to budget may impact the work in the M-290. During these reviews the facility model has provided output showing where overlaps will occur and how splitting work in the facility between two programs simultaneously would negatively impact performance. The results have allowed the production team and the customer to discuss alternatives and ensure that the schedule overlaps are avoided, to preserve the desired schedules and deliveries.

Along with the M-290 facility model, the shipyard maintains multiple other models of facilities and processes associated with the nuclear work on aircraft carriers. In an effort to increase the scope of questions the models can support, the shipyard is currently working to integrate the nuclear operations models, to address larger operational questions. The efforts will allow the M&S team to examine throughput of the entire yard, from a nuclear material perspective, identify bottlenecks well in advance of schedule impacts, and help ensure staffing levels remain ideal. The result of this effort will be a new methodology for linking multiple simulation models together to address larger questions. While the integration of simulation models currently occurs frequently, often in a distributed fashion, the fidelity of the integrated models is not to the detail present in the NNS systems. The unprecedented detail in the models, combined with their integration, will result in a robust system to address the entire SNM handling process within the shipyard, resulting in increased planning accuracy and improved execution.

Future Planning

While these tools support the current operations, they are also serving the role of data capture tools. The models run with updated information provided via the "actuals input sheets", accumulating as the work progresses. By creating a database of these historical progressions, the models will support planning for future deactivations. The tools will allow the users to go back and observe specific periods during the deactivation, using actual information from that period in the process. The visual components of the model will then allow planners to observe how work progressed during these periods. Any delays which arose will also be apparent. As the planning team moves to preparing for the next deactivation they can utilize this information to refine plans. They will also be able to use the models to assess different deactivation strategies and assess their likelihood of success. Coupling this capability with traditional scheduling techniques will result in better schedules and reduced risks.

By combining the historical data with the simulation models, NNS will also ensure that the simulation models support "what-if" experimentation for future efforts. The tools are already supporting assessments of how program overlaps would negatively impact performance, but in the future the tools will also provide planners with an experimental tool to test better ways to organize and execute work. The tools will allow planners to test new ways to group and execute work, based on their expertise, and provide them with accurate outputs to determine if each scenario they analyze is a worthwhile endeavor. Additionally, as the shipyard begins to deal with the effects of the generational workforce gap, these tools will provide a documented history to new planners, allowing them to essentially draw on the knowledge of the retiring workforce in a more efficient manner. Combining this captured knowledge with the tools as experimental platforms will let the new generation of planners learn in the "lab" rather than requiring two or three ships to come and go before they truly understand all the complexity they must plan for.

CONCLUSIONS

The use of M&S within the M-290 is leading to increased risk avoidance and increased performance. The tool's ability to support the production team as they plan and execute operations is ensuring that any limits to the ideal performance of the M-290 are known and mitigated as early as possible. The documented uses of the models to create accurate schedules, experiment in a controlled and cost effective environment to test new processes before implementing them, and identify ideal equipment locations is leading to increased team performance. As the M-290 transitions from its first use for the USS Enterprise to use for overhaul operations on other Nimitz class carriers, these tools will continue to support production and planning personnel as they work out the ideal operational plans for the facility, better accounting for potential risks and other program challenges. NNS plans to continue to utilize these tools and expand their capability to capture additional touch points to the M-290, to increase their fidelity, and provide further increases in performance.