Nuclear Aircraft Carrier Inactivation – Approach for Waste Management and Exposure Reduction – 14201

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ABSTRACT

Since 2007, Newport News Shipbuilding (NNS) has been planning for the inactivation of USS Enterprise. With this unique history and design come unique challenges, specifically, in the areas of radiation exposure and waste management. USS Enterprise defueling will involve decommissioning of eight nuclear reactors. Due to the large quantity of radioactive waste being generated for the inactivation, the standard process for managing radioactive waste on the ship would not be feasible. In addition, USS Enterprise is the first to implement a new approach to defueling aircraft carriers. This approach was a result of a newly designed storage container. To accommodate this container, a new spent fuel handling facility was designed and constructed at NNS. NNS has undertaken many initiatives using latest in technology and best practices in waste management to execute this nuclear aircraft carrier inactivation safely and efficiently. Among these are streamlining waste management processes and applying simulation based tools for more efficient planning and execution. A modernized process was implemented to enable loading radioactive waste directly into waste containers on the ship, and then loading the shipping container onto a truck to be directly shipped off-site to a disposal facility. NNS utilized its advanced simulation capability to create tools for decision making in the inactivation. For detailed planning, defueling operations simulation supported schedule development and was expanded into a radiation exposure prediction tool, 3D spatial arrangement tool as well as a training tool.

INTRODUCTION

Since 2007, Newport News Shipbuilding (NNS) has been planning for the inactivation of USS Enterprise, which began in June 2013 following 51 years of naval service. The ship's unique history and design come with unique challenges, specifically in the areas of radiation exposure and waste management. USS Enterprise defueling involves decommissioning of eight nuclear reactors. The defueling and inactivation work to be performed includes removal of interferences, defueling components, various systems, and special tools and equipment. In addition, USS Enterprise is the first to implement a new approach to defueling aircraft carriers, utilizing a newly designed dry storage container and a new spent fuel handling facility. To prepare for this complex endeavor, NNS has implemented several improvements, redesign, and technology insertion initiatives. One of the technologies utilized is advanced simulation capability to create tools for decision-making.

BACKGROUND

Built by NNS and commissioned on November 25, 1961, USS Enterprise is the world's first nuclear powered aircraft carrier and the only ship of its class. In June 2013, USS Enterprise began its inactivation, a process that lays up a ship for safe storage pending disposal or for long-term storage in the event of mobilization. The inactivation phase will last approximately four years. As part of the inactivation, hydraulic systems will be drained, and expendable materials, tools, spare parts, and furnishings will be removed. Additionally, tanks containing oil and other fluids will be drained and cleaned, any hazardous material will be removed, and the ship's electrical and lighting systems will be de-energized. Concurrent with inactivation, the ship's defueling will occur, using the same proven techniques that have been used to refuel and defuel over 350 naval nuclear-powered warships successfully. The ship also will be prepared to be towed to Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS&IMF) in 2016 for dismantlement and recycling [1].

NNS started planning for the inactivation of USS Enterprise in 2007. The ship's unique history and design bring with them unique challenges, specifically in the area of radiation exposure and waste management, and with the introduction of a new spent fuel cask. NNS has undertaken several initiatives to tackle these challenges, including process improvements, process and equipment re-design, and technology insertion. In the area of technology, NNS applied its unique Modeling and Simulation capability to create simulation based decision support tools.

AS LOW AS REASONABLY ACHIEVABLE (ALARA) INITIATIVES

As an industry leader in nuclear ship manufacturing, construction and overhaul, NNS strives to reduce radiation exposure using the As Low as Reasonably Achievable (ALARA) concept throughout the planning and execution process. One of the main risks associated with the Enterprise defueling is the high radiation exposure potential. With the Enterprise defueling being the first of its kind, NNS is faced with the challenge of estimating radiation exposure, which is further increased by sharing manning with the Nimitz class aircraft carriers refueling program, while driving ALARA initiatives. Historically, exposure estimates were developed using a top down approach based on actual returns from similar operations. For Enterprise defueling, the initial exposure estimate used a bottom up approach based on over two thousand work packages including man hours estimates, worker positioning, dose rates, and differences between each reactor.

By utilizing best practices leveraged from aircraft carrier refueling, several exposure reduction initiatives were put into place in order to drive towards the ALARA goal. Some of the exposure minimization methods include 1) increased amount and strategic placement of shielding, 2) improved designs for temporary systems based on lessons learned, 3) use of standard grid system across all naval shipyards to identify worker location and duration, and 4) other tooling and process improvements. One of the reduction efforts was the use of HotGuard™[a], a lead-free and non-hazardous gamma radiation shielding product developed and produced by Newport News Industrial, a subsidiary of Newport News Shipbuilding. HotGuard™ is light and easily manipulated to fit into difficult to access spaces and outperforms standard lead wool blankets.

In concert with R&D, demonstrations and risk analysis reviews, NNS set out to re-engineer the defueling process and refine work techniques and identify opportunities to reduce exposure. To help test exposure reduction ideas and support planning of ALARA initiatives, NNS developed a simulation based aid for radiation exposure predictions. The tool combined industry standard calculations with a stochastic simulation of defueling operations complete with detailed worker positioning during each task. As the operations are executed in the simulation and the corresponding sources move in and out of the environment, the algorithm continuously re-calculates the fields. This allows the simulation to track each individual's accumulation based on where that person is at any given point in time and what the fields are where that individual is standing. This method mimics the way radiation exposure is tracked in real life via Thermoluminescent dosimeters (TLD).

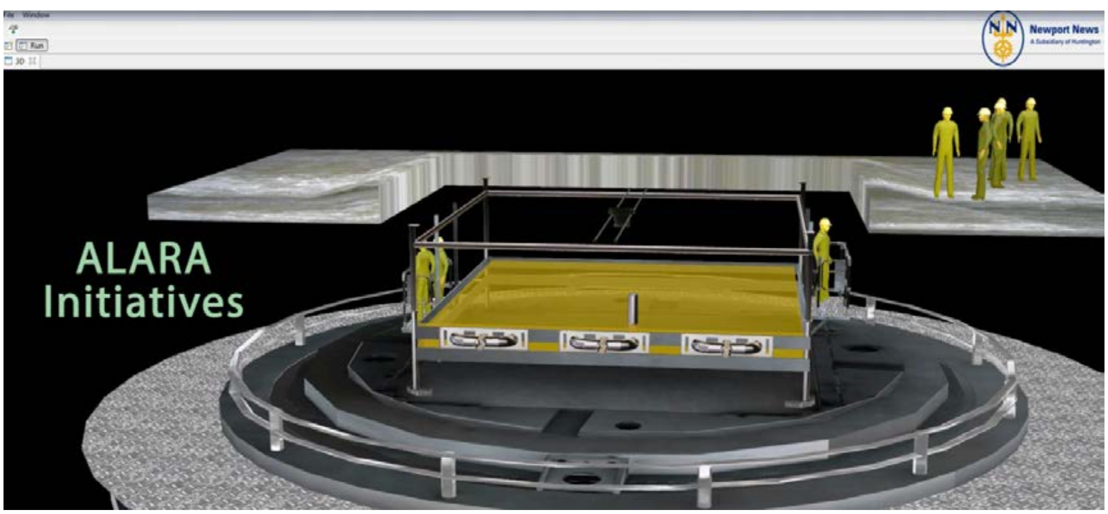

Figure 1: Simulation based tools support ALARA initiatives.

[a] Trademarked by Newport News Industrial

The resulting accumulation levels are used to conduct a number of analyses. The data is used to quantify the risk associated with working on a specific operation, position or working as part of a team that is trained to do specific tasks. The data also supports ongoing projections and estimations conducted as part of the decommissioning planning and execution work. By identifying the areas with the highest accumulation potential, the tool helps focus the ALARA initiatives on the big ticket items. In addition to predicting radiation exposure accumulation, the tool serves as the experimentation platform for evaluation of process improvements, new shielding or other ALARA initiatives. This tool allows quickly assessing and quantifying the value of the proposed improvement, thus facilitating evaluation of many more ideas than can be considered with traditional methods.

WASTE MANAGEMENT PLAN

As part of the planning phases of the Enterprise inactivation, NNS developed a new and innovative waste management plan. Projections showed the volumes of radioactive waste from this effort would be significantly greater than past nuclear operations projects. The overall goals of the planning were to streamline the generation and disposal process for radioactive waste to ensure the efficient handling and disposal, minimize risk and radiation exposure to personnel and the environment, and maximize the benefits to NNS and the customer.

Implementation of a specialized waste management plan for inactivation was necessary to alleviate the competing needs of other concurrent programs at NNS for shipyard resources. NNS determined it was most efficient to remove radioactive waste directly from the point of generation and transport directly off of the ship. A similar waste handling method was proven effective with a local dry dock demolition project.
A variety of waste processing efficiencies were evaluated to enhance the waste management plan for the Enterprise inactivation, including the following:

- Establishment of a Waste Packaging Area (WPA) onboard ship to maximize waste loading and shipments.
- Simplification of the waste tagging process provides an efficient method for tagging waste items and reducing the number of times radioactive material is moved.
- Establishment of NNS and waste vendor teaming effort to facilitate efficient handling and processing of inactivation waste, container design and supply, and waste shipments.
- Use of simulation based tools, such as the spatial arrangement tool (SAT) to determine the most effective locations for positioning shipping containers, and a corresponding waste processing simulation to determine the most efficient process flow for moving waste from the plant to the WPA.

A major efficiency initiative of NNS's waste management plan was the establishment of a WPA aboard the ship to assist with the disposal of the large quantity of waste expected to be generated during the inactivation. A WPA of this size and scale had not been performed in the past at NNS. The WPA consists of a material receipt and holding area, temporary radioactive polychlorinated biphenyl (PCB) storage area, and waste holding area, and it allows for efficient waste packaging and shipment of waste straight from the ship.

Another initiative for the waste management plan was the simplification of the waste tagging process. Removal of equipment/material from the plant directly into shipping containers and the use of 1.2 cubic meters (1362 kg capacity) waste containers allowed the use of "One Container One Tag" process. This process reduced the number of personnel handling the waste and minimized personnel radiation exposure. The use of these waste containers also reduced the number of radioactive material movements by 90 to 95 percent and the tagging and placement of radioactive material/waste into an accountability system for tracking. As a result, both personnel radiation exposure and the transfer of waste from the ship to the other facilities for processing and shipment were minimized.

Additionally, teaming with the disposal site provided additional improvements to the inactivation waste management plan. Involving disposal site personnel in the planning phase allowed for the development of the most cost effective and efficient process for disposal of waste at their sites. The disposal site also helped design specialty equipment shipping containers to determine the best path for disposal. Due to the higher than normal radioactive waste shipments, the disposal site also will broker the shipments onsite to streamline the waste disposal process and shipment offsite.

During the planning phase of the waste management project, all waste items expected to be generated during the inactivation were identified and pre-characterized. The exercise evaluated inactivation waste streams and identified which waste streams could be consolidated. Waste types with similar characterization were consolidated under applicable waste profiles. NNS worked with the disposal site personnel to effectively develop waste profiles in accordance with the site requirements and the inactivation waste's characterization. In turn, this reduced radioactive waste transfers from the point of generation to the WPA. The strategy also reduced costs by limiting the number of containers required to ship waste offsite

Finally, NNS's use of simulation based tools to support movement and shipment of waste containers built on previous successes of applying similar tools to nuclear refueling and other operations. One of the tools developed for this effort was a spatial arrangement tool (SAT). SAT consists of a 3D "canvas" representing the space and a gallery of 3D models of the equipment to be placed in the space, as shown in Figures 2 and 3. This easy to use tool allows the user to quickly arrange the space by rearranging, resizing, and positioning the objects as desired, within spatial restrictions.

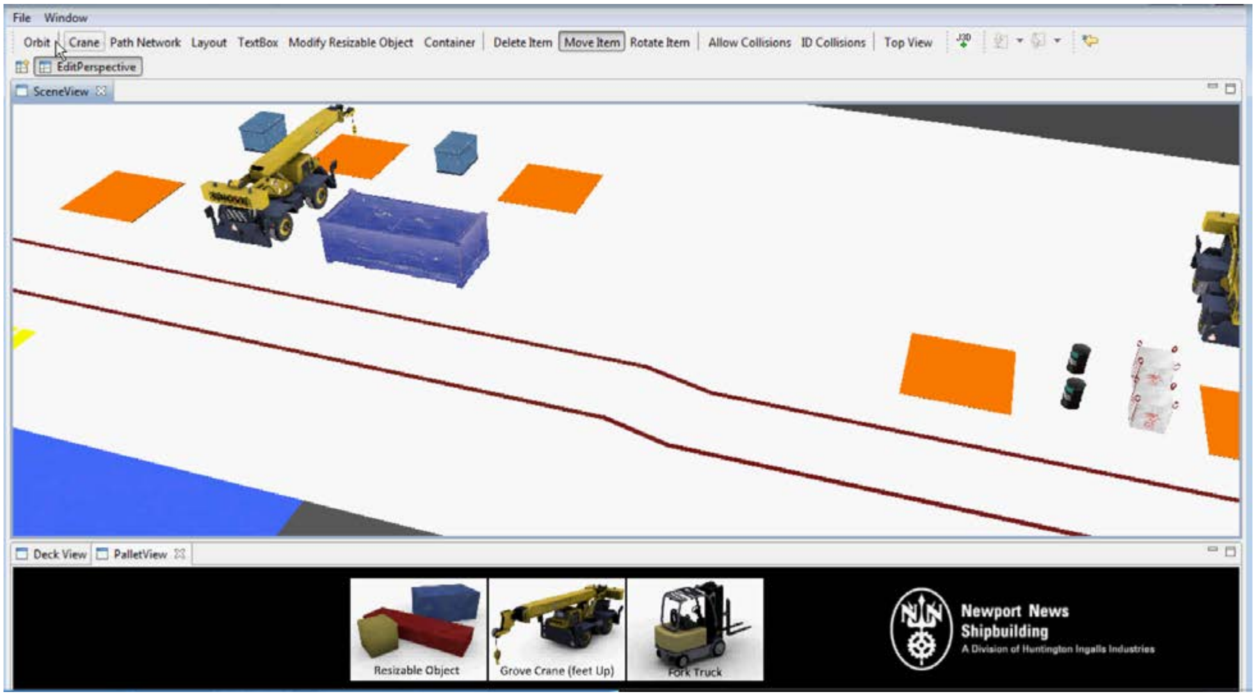

Figure 2: Spatial arrangement tool for waste management activities enables users to arrange a space by moving around objects in a 3D space.

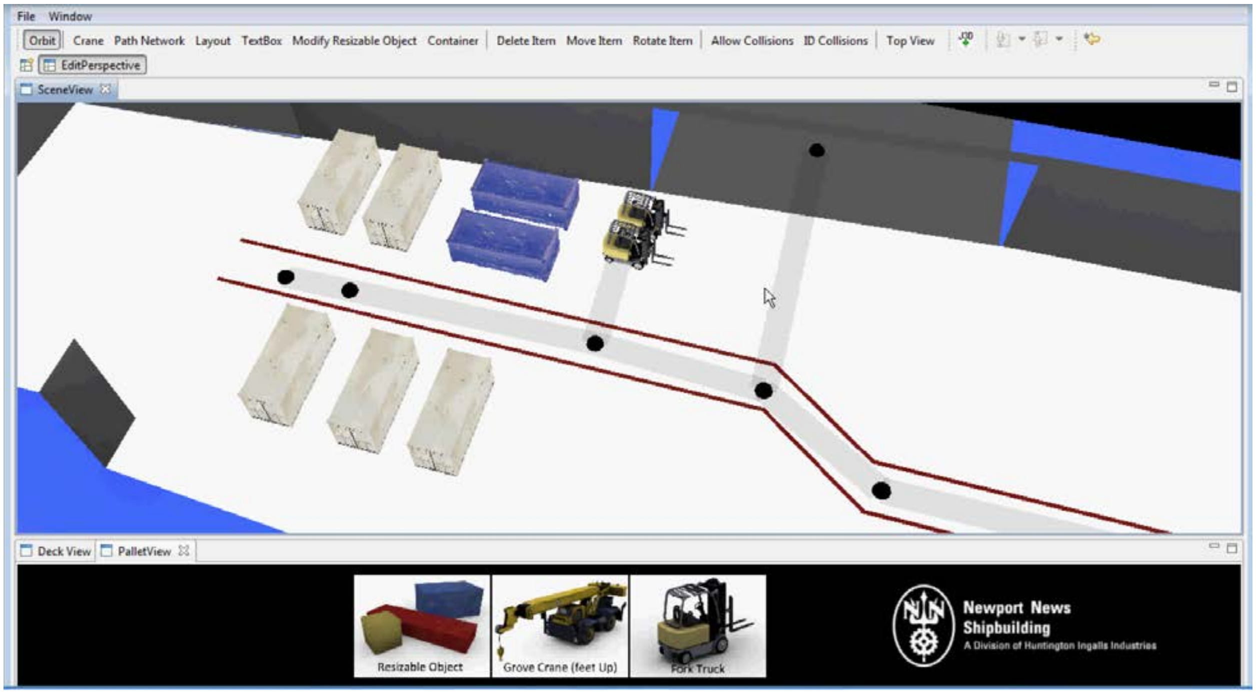

Figure 3: Simulation capability allows users to dynamically assess the waste flow within the layout.

The tool was used to determine the most effective locations for positioning shipping containers and to establish the interferences with existing equipment/components on the ship. In addition to the ability to lay out the space to the desired arrangement in 3D, the user can specify material routing and instantly simulate the waste removal process within that arrangement. For waste management planning purposes, the simulation component of the tool captured the operational elements of the waste flow process, such as waste removal activities, durations, required personnel and equipment, and material routing and locations, which allowed the user to dynamically assess the functional value of the equipment/material arrangement. This tool was designed with the utmost flexibility to allow users to experiment with various options.

SPENT FUEL HANDLING UPGRADES

The M-290 System is a new, more efficient transportation container system for aircraft carrier spent fuel that replaces the M-140 used in previous refuelings. This new system was necessary to support Fleet schedules [2]. This need was expressed by Admiral Kirkland H. Donald, director of Naval Nuclear Propulsion at the time of introduction of this cask, when he said at the Energy and Water Development Appropriations for 2012 “We reach this period of time when there is heel-to-toe aircraft carrier refuelings. One comes in, gets refueled, it goes out, another one comes in right behind it. We cannot do that unless we change the way we remove the fuel from the ships. To be able to do it more efficiently, we had to have a new shipping container and a new fuel handling system, and [existing] water pit is not ready to accept that type of fuel [3].”

Previously at NNS, naval aircraft carrier spent nuclear fuel assemblies were disassembled after removal from the ship to fit into the current design naval spent fuel shipping container, designated the M-140 shipping container. The use of the M-290 shipping container allows for the direct loading of aircraft carrier spent nuclear fuel assemblies into the shipping container without the need for prior disassembly at the Surface Ship Support Barge (SSSB). Since existing NNS facilities are not adequately sized to support loading the new longer shipping container, a new M-290 loading facility was needed [4]. Removal of the SSSB and M-140 eliminated the maintenance and reconfiguration cost of the barge and reduced radiation exposure to personnel and the number of labor-intensive and costly crane lifts. It also reduced Special Nuclear Materials processing time for shipment, which supports undocking and ship delivery based on a 36- to 40-month Nimitz class Refueling Complex Overhaul (RCOH). However, the first use of the M-290 system was not intended for the Nimitz class or future carrier designs but rather for the defueling of the one-of-a-kind Enterprise.

The M-290 cask is very different from the M-140 cask, as shown in Figure 4, and it required the design of the new M-290 facility and new procedures for packaging the spent fuel. The M-290 cask was designed to hold more radioactive material while maintaining the radiation levels exhibited by the M-140 cask.

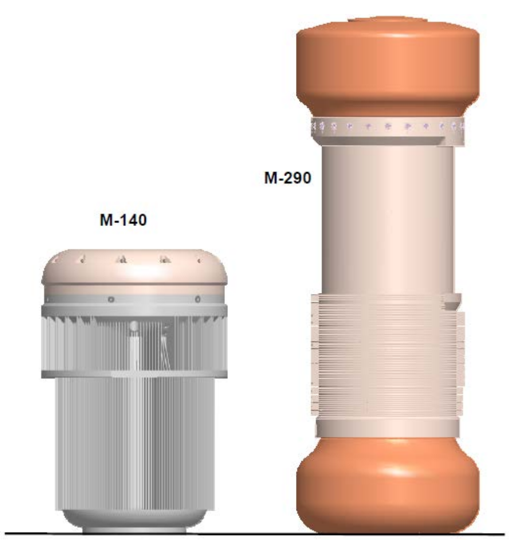

Figure 4: The M-290 Shipping Container is being used for the USS Enterprise Inactivation instead of the M-140 container [2].

Space restrictions, equipment locations, and procedures are some of the constraints involved in operating a production facility. A Spent Nuclear Fuel (SNF) handling facility like the M-290 facility deals with additional constraints, such as uniquely shaped, large equipment and radiological controls. In constructing the M-290 facility, NNS created a simulation based decision support tool to assist with layout and staging decisions, offer predictability, and alleviate the risk associated with its unique constraints. To develop this tool, NNS set out to capture all the relevant aspects of the facility with a 3D representation of the building, processes, equipment, people, cranes, and containers. NNS used a Building Information Model (BIM), created as part of the Architecture and Engineering (A&E) work on this facility, to use as the 3D model basis for the simulation and to create the spatial arrangement capability similar to the one used in waste management simulation tool, described above. It also was used as the visualization for an operations simulation, similar to the one used in ALARA initiatives, described above.

By creating a virtual representation of the facility, its processes, resources, and variable parameters, NNS developed a tool to aid decision-making throughout the facility's lifecycle. Some studies conducted using this tool included analyses of alternatives to determine the best equipment and storage layouts, assess different operations approaches, validate schedules, forecast manning levels required to support operations, evaluate different team sizes, and understand impact of manning levels and shifts on production.

Today, the tool is transitioning to becoming a training tool. The immersive nature of a 3D simulation provides a safe and realistic environment for training an individual or a team to interact with and learn about equipment, work to procedures, reinforce good safety habits, and learn the response procedures. It is also a cost effective method of procedural training of a large or geographically dispersed workforce, frequent refresher training, and scenario based response training. This capability expands the use of the tool from familiarization training to qualifications and even team building.

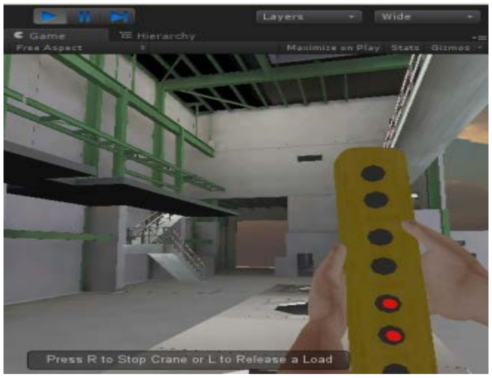

Figure 5: The M-290 Facility simulation is being used to create immersive interactive crane operator training.

CONCLUSION

During inactivation of the one of a kind aircraft carrier, the Enterprise, eight nuclear reactors will be defueled, approximately 3,000,000 pounds of waste will be generated which includes, but is not limited to, non-hazardous waste, mixed waste, radioactive asbestos, recyclable metals, regulated and non-regulated polychlorinated biphenyls (PCBs). The inactivation will be the first time a brand new spent fuel container and a corresponding facility will be utilized. NNS has undertaken many initiatives using latest in technology and best practices in nuclear operations and waste management to execute this nuclear aircraft carrier inactivation safely and efficiently. Among these are streamlining waste management processes and applying simulation based tools for more efficient planning and execution.

NNS utilized its advanced simulation capability to create tools for decision making in the inactivation. To support detailed planning, defueling operations simulation supported not only schedule development but was expanded into a radiation exposure prediction tool. This tool was used to protect the workforce performing the decommissioning work and support As Low As Reasonably Achievable (ALARA) initiatives. To ensure that the new facility is properly equipped for the required throughput and the staging strategies facilitate required waste flow, the 3D spatial arrangement tool was used in conjunction with a simulation, supporting decision making and “what if” analyses. The use of simulation tools expanded into training to offer novice workforce an immersive environment to familiarize with specialized equipment and procedures.

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