An Adaptive Planning Tool For Air Craft Carrier Specialized Tank Inspection And Overhaul

Nick Drucker
Newport News Shipbuilding
Newport News, VA
David.N.Drucker@hii-nns.com

Jeremy Hancock
Newport News Shipbuilding
Newport News, VA
Jeremy.E.Hancock@hii-nns.com

ABSTRACT

The maintenance and overhaul worked performed on US Navy air craft carriers may be the most challenging industrial and engineering task undertaken anywhere by any organization (RAND National Defense Research Institute Study, 2002). During this complex process, sets of specialized tanks can cause unforeseen ripple effects on the entire overhaul process. In this paper, we introduce the utilization of M&S to create a tool for adaptive planning of specialized tank inspection and overhaul. This tool utilizes discrete event simulation, implemented in NNS's own simulation engine, to replicate the complex job processes involved in this work. This tool allows NNS to support work by providing an adaptive planning capability, accepting data about performance to date and providing likely scenario outcomes. Additionally, the tool supports pre-planning for future carrier work in these specialized tanks, taking previous performance measures and using them as a baseline to assess proposed new work methods.

ABOUT THE AUTHORS

Nick Drucker is a Modeling and Simulation Systems Engineer at Newport News Shipbuilding. In this role he supports the creation, implementation and maintenance of simulation models to support decision making during the overhaul process for Naval aircraft carriers. Mr. Drucker has worked on multiple overhaul simulations covering operations across the entire overhaul process. Prior to working for Newport News Shipbuilding Mr. Drucker served as a research analyst, senior analyst, and later the manager of analysis and product design for a small business specializing in Modeling and Simulation solutions for government and commercial training organizations. Mr. Drucker possess a Master's Degree from Old Dominion University in International Studies with a concentration and certification in Modeling and Simulation. He also possesses a Bachelor's degree from Christopher Newport University in Political Science with a minor in Psychology.

Jeremy Hancock is a Modeling and Simulation Apprentice at Newport News Shipbuilding. In this capacity he supports the development, construction and use of NNS simulations supporting the entire Naval aircraft carrier overhaul process. Mr. Hancock also led the deployment and use of the specialized tank inspection and overhaul simulation, ensuring its successful utilization as a decision support tool. Prior to working as a Modeling and Simulation Apprentice, Mr. Hancock worked as a shipfitter on both overhaul and new construction for Naval aircraft carriers and Naval submarines. He has worked as a shipfitter on the USS Theodore Roosevelt, USS Gerald R. Ford, USS Mississippi (SSN-782), USS California (SSN-781) and USS Missouri (SSN-780). The experience he gained as a trade worker has given him a working knowledge of processes and a mutual relationship with customers at Newport News Shipbuilding.

An Adaptive Planning Tool for Air Craft Carrier Specialized Tank Inspection and Overhaul

Nick Drucker
Newport News Shipbuilding
Newport News, VA
David.N.Drucker@hii-nns.com

Jeremy Hancock
Newport News Shipbuilding
Newport News, VA
Jeremy.E.Hancock@hii-nns.com

Introduction

One of the more involved processes in the overhaul of aircraft carriers is the inspection and refurbishment of specialized tanks. These specialized tanks are historically part of the critical path to successful overhauls. During the current overhaul, the production team responsible for inspection and overhaul of these tanks instituted new procedures for tank entry among other changes designed to reduce the critical path impact of these tanks. To support this team in their efforts Newport News Shipbuilding (NNS) created an adaptive planning simulation model as a means to assess the new process effectiveness, support the production team in planning around roadblocks during execution, and create a database of past ship performance to further increase efficiency on future ships. In order to create this adaptive planning tool a NNS development team created a discrete event simulation (DES) of the entire inspection and overhaul process. The simulation models development utilized NNS's Common Simulation Framework (CSF), a set of Java based simulation tools, with input data validated and verified by Subject Matter Experts (SME's) with experience on previous specialized tank refurbishments. The purpose of the adaptive planning tool is to allow production team and planning team members to evaluate new process against past work, identify potential benefits of these new processes, and refine them prior to execution work beginning. In addition, the adaptive planning tool supports active production work on the tanks in the shipboard environment, through use by a modeling and simulation apprentice. The apprentice works with the production team to identify the status of work, highlight potential roadblocks to allow for pre-planning and risk mitigation, and provide near real time situational awareness of project work paths. The tools dynamic format also allows the development team, through the apprentice, to track actual work and delays in real time, greatly increasing the adaptive ability of the model and creating a base for assessment of new plans on future ships.

Problem Space

The overhaul of naval aircraft carriers is one of the most complex processes undertaken by an organization, anywhere (Birkler & Chiesa, 2002). In addition to the overhaul work performed on a majority of the tanks within the ships, there are specialized subsets of tanks, which require more intricate inspections and overhaul work. As a result, these specialized tanks have the ability to impact the overall overhaul duration and completing them as efficiently as possible is essential. The main challenge these tanks present is in executing work concurrently. In order for crews to work the tanks efficiently they often need to coordinate and execute complex plans that span several months. Even minor disruptions to these plans can have unforeseen and potentially negative effects on the timeline for tank work. As a result, NNS identified modeling and simulation as a viable toolset with which to tackle this problem and created an adaptive planning tool for the specialized tank inspections and overhauls.

The simulation model uses the production teams detailed work plan as its base. A development team from NNS constructed the model from this base, using information from SMEs with experience from multiple previous overhaul processes, to create a realistic representation of the work planned for these tanks on the current ship. The model supports the production team by allowing them to analyze the known processes of the inspections and overhaul, taking into account potential delays such as weather or limitations on concurrent work, and evaluate how likely their plan is to succeed in meeting their time goals. The model also supports them by allowing for "what-if" analysis so the team can analyze expected and unexpected possible delays and pre-plan courses of action to mitigate their effect on overall work times. The model construction and deployment has successfully allowed the production team to identify and mitigate several potential roadblocks, and has allowed them to examine courses of action to work around unforeseen conditions present on the ship, a common occurrence but one that cannot be fully pre-planned.

Model Structure

The use of modeling and simulation in this effort is primarily supported by prior models constructed to support previous ships and other ship yard operations. To construct this model the team utilized a discrete event software developed internally (Common Simulation Framework, CSF). CSF is an open framework software which allows the user to create robust and flexible simulation models.

For the specialized tank model the team utilized a novel system framework. Rather than traditional DESs which construct "stations" where entities arrive and are processed, the specialized tank model treated the steps in the process as the stations and the tanks as entities which flow through the steps. This is in line with previous models of complex carrier work, which applied this concept to the entire tank overhaul process (Shaffer & Mook, 2013). By creating a system where the steps in the process serve as "stations" and the tanks are "mobile", the team was able to create a tool that could be reconfigured over an hour or two, and without modification of the model source code. This significantly increases the use factor for this model in a shipyard environment where the target audience will not be able to dedicate a week or more to re-construct process as they change dynamically.

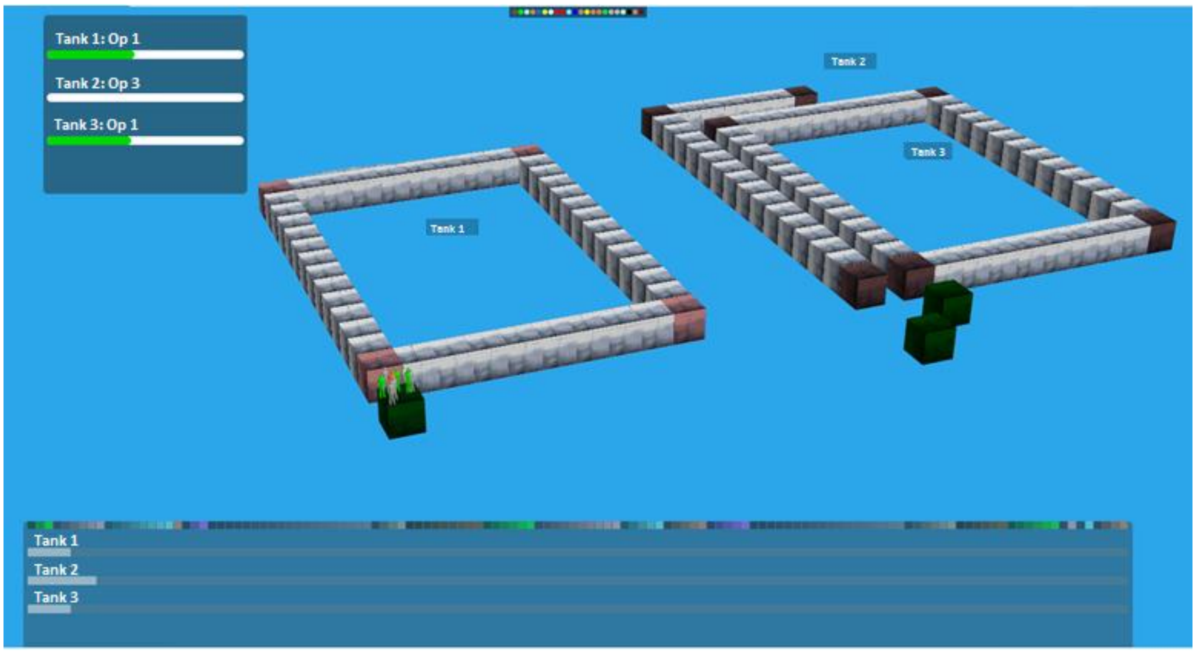

Figure 1. An example of a visual run of the model (redacted)

To further support this flexibility the team created a set of input sheets which a user can modify, and through this manipulation re-construct the entire model logic. Removing the need to perform recoding of the model, and removing the necessity for the user to have robust programming capabilities allowed the team to move use of the model to a deployed apprentice, who could take information provided in a morning meeting, update the model, and provide output by the afternoon of the same day. The reduction in specialized computer programming skills or even detailed M&S expertise allows this model to support production work in the yard environment, rather than requiring support from a remote team with the specialized skills needed to rework model source code or detailed model logic.

To support analysis of the model output the team developed a set of analytical features within the model. To facilitate robust data the model generates a database of outputs across the totality of the simulation runs. The development team dynamically assesses the number of simulation runs required to create reliable outcomes by performing number of runs analysis any time a process change occurs. The model then generates a set of output charts drawing from the database. The analysis charts support the production team on a daily basis, and as such need to be easy to interpret and understand, to reduce time required to examine the data and draw inferences. To facilitate this, the development team created a set of charts to summarize data relating to: equipment utilization and manning utilization, process times, simulated delay occurrences, and overall inspection and overhaul durations.

Examples of some of these charts appear in figures 2 and 3 below. After every model run these charts automatically generate and the user is able to then use one of several filter features to “drill down” into the data and create the output required to support the production team. The model accomplishes this filtering and chart creation using several drop-down menus and text fields, reducing the overhead associated with traditional data assessment using data analysis tools.

Intended Uses

The flexible nature of the model and the intent to deliver it to shipboard environments allows production teams to make use of the model on a near daily basis to track progress and plan work. Initial use of the model, prior to arrival of the current ship, focused on planning the inspection and overhaul work and providing support to assess the new work strategies planned for this ship.

Planning

During the initial planning phase, the model supported the production team as they developed new work plans for the tank inspection and overhaul processes. Based on past performance with ships the team decided to attempt a new method, not previously used, in hopes of reducing work times and increasing parallel work lines. Because this process was new, the team employed the model to assess whether the planned strategy was likely to result in the type of timesavings they anticipated. The development team constructed the model, working with the production team to identify a detailed work plan and anticipated work times for each step of the process. The production team then compared a set of model runs using the new process against known data from previous ships. The resultant output helped the production team work through modifications of their process and supported their anticipation of increasing productivity on the current ship. Outlined in the “Use on the current carrier” section below are several examples of the types of savings the model helped to identify during initial planning.

Deployment

The models second function was to support current ship operations. By deploying the model shipboard with an apprentice responsible for keeping its information current and providing daily outputs, the development team’s aim was to support risk mitigation and situational awareness of overhaul work. The model structure allows it to accept information about current tank status, ensuring it remains completely up to date during the overhaul process and that as work progresses the model output reflects work already performed. The use of the actual status of the ship as the starting point for analysis during overhaul work allowed the production team to identify potential roadblocks and other delayers, and effectively pre-plan how to handle them. The model also highlights potential future constraints, including resources and equipment, to allow the production team to redeploy personnel or order additional supplies far enough in advance to avoid delays associated with securing the required resources.

Use on the current carrier

During the pre-planning and actual overhaul work, the model served its purpose of supporting the production team in mitigating risk, developing work plans, and executing the work efficiently and effectively. During pre-planning, the model served as a tool for use by planners and schedulers to assess the likely success of shipboard work. Following the arrival of the current carrier and deployment of the model, the system supports daily briefs and has identified several potential bottlenecks and risks, which the production team has been able to address immediately and reduce their overall impact.

Pre-Planning

The new process the decision support tool supports involves the method of entering the specialized tanks for inspection and overhaul. The basis for this new process was the expected cleaner method of entry and the possible elimination for rework that occurred historically on every overhaul. Prior to operations beginning, the team used the model to show any possible time saving benefits associated with the new operation when compared to modeled legacy operations based on subject matter experts (SMEs) to complete entry into the specialized tanks. After a set number of model runs, based on a replication study, the team determined while the new process would save time for entering the tanks compared to the legacy process, other processes associated with inspection and overhaul in the tanks would cause the expected time to complete work to lengthen. However, because of the savings the model showed in other areas of work, the production team determined that the other benefits outweighed the increase in schedule, and the overall effect of the new plan would result in a more efficient and effective overhaul process.

Another area where the model supported planning work was in the inclusion of "global delays"; a set of historical categories of delays experienced on past ships, which affect the entire overhaul process by limiting some or all work on the tanks. These global delays allow the model to more accurately reflect expected actual work, and help the production team better visualize and plan the work. During pre-planning the inclusion of these delays highlighted to the production team the likely schedule impacts they could expect, given the occurrence of any of the global delays. Based on the model output the team was able to develop mitigated schedules, using the model to validate their effectiveness, which offer varying alternatives to return the schedule to an acceptable range, should any of the "global delays" arise. In the past creation of these mitigated strategies would require a delay to occur before re-planning.

During inspection and overhaul work, shift schedules and available personnel (manning) have one of the larger effects on overall work times and work efficiency, as well as impacting the amount of concurrent work which it is possible to execute. The production team initially had a set shift and workweek planned for all operations during overhaul. However, the model indicated that altering shifts and manning on particular operations drove down the duration of the operation significantly while other operations saw no significant impact. Focusing on those steps with the greatest impacts, the team was able to create a set of scenarios which could further reduce work times and total tank completion times.

Table 1. Example of mitigation time savings

	Right Tank		Left Tank	
Step Name	Expected Date	Improvement (Days)	Expected Date	Improvement (Days)
Entry	10/03/13		10/03/13	
Cleaning	11/28/13	**11.8**	11/26/13	**9.5**
Install Protection	12/11/13	**11.7**	12/13/13	**8.4**
Inspection	02/22/14	**19.5**	02/07/14	**22.0**
Repairs	02/28/14	**20.1**	02/13/14	**22.7**
Paint	03/08/14	**25.0**	02/19/14	**27.0**
Remove Equipment	05/18/14	**41.5**	04/30/14	**46.3**
Final Test	05/22/14	**41.1**	05/05/14	**46.1**

Overall Time Savings (Days): **38.34**

Execution

Following the use of the model during the planning phase the team moved into execution with work on the current carrier. As part of this process, the model was moved to a shipboard environment and a full time shipyard modeling and simulation apprentice was designated to move with the model to the production location to track actual progress on the ship and provide immediate simulation data for use by the production team. During this execution phase, the model continues to successfully aid in the re-planning of critical path processes and provides a daily update to the team on progress, identifying potential risks to successful completion of the work. The work for the ship is planned to continue through 2014 at which point the model will transition to supporting the planning of the next carrier ahead of its arrival for overhaul.

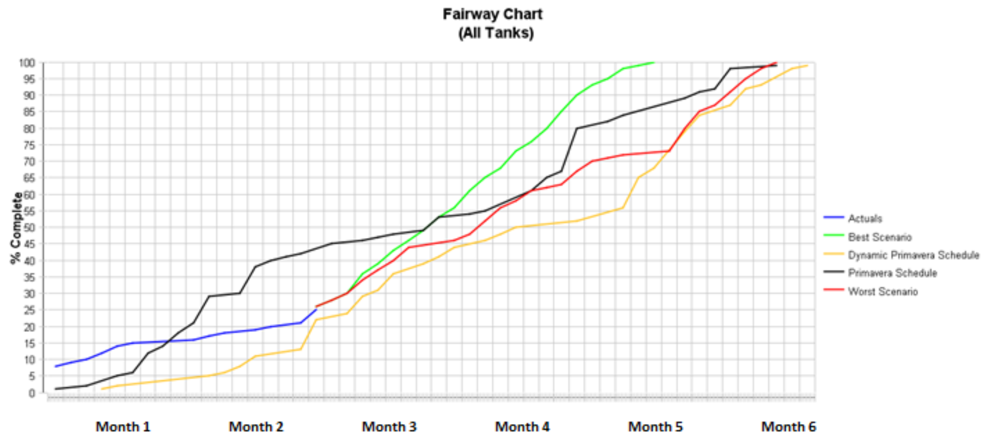

Figure 2. Example model output of current work status

Equipment and Resources
The model deployment began during the qualification phase for key workers on the specialized tank overhaul. During this time the team validated model step times, using actual data from qualification training. The team also used model run data to assess how well the qualification training tracked with expected performance times. The model did not require any modification following this data gathering and tracking, but the development team did identify a potential delayer during key steps in the process.

During the specialized tank process, workers are required to put on extra layers of equipment. This results in a time lag from when the workers begin their shifts and when they are able to work on the tanks. During initial creation of the model, the team was aware of these dressing times and created a variable to account for them inside the model. The team observed that during qualification runs the actual time required for workers to put on the gear was significantly less than initially planned. When the development team factored in the reduced dressing times during these steps, the model showed a one-month reduction in expected work time. The development team presented the results of the finding to the production team and collectively the groups decided to closely monitor actual dress times during execution to determine if other factors may contribute to a longer dress time during actual work. The production team also noted the need to work as hard as possible to keep these times to a minimum and identified these steps as vital to the success of the overhaul work.

During execution, the first instance where the model was required to assess a change to work plans occurred during the first phase of work. During this time, unforeseen ship conditions necessitated a modification to the original work process. The production team utilized the model to assess two paths forward, comparing their suggested outcomes against the baseline. The result demonstrated the conducting work on a piece of infrastructure in the dry dock, required to perform later steps in the process, several weeks ahead of schedule would allow the team to modify the original plan without dramatically impacting the overall schedule. Based on input from the production team members and the model output, the infrastructure work began three weeks ahead of schedule and the team amended the original process to allow for the actual ship conditions.

Shifts and Manning
As work progresses on the ship, the production team uses the model to continuously monitor the projected number of trades workers required to keep the process on track. As the model identifies manning shortages the team is able to actively secure additional personnel weeks in advance. A specific example of this occurred when the model identified that by adding one additional trade worker for steps occurring inside the tanks, the team could work two tanks in parallel, rather than a single tank. The model identified this need, with input from the development team, two months in advance of when the work was scheduled to begin. This allowed the production team to secure the required personnel, train them, and make them available in time to support simultaneous tank work.

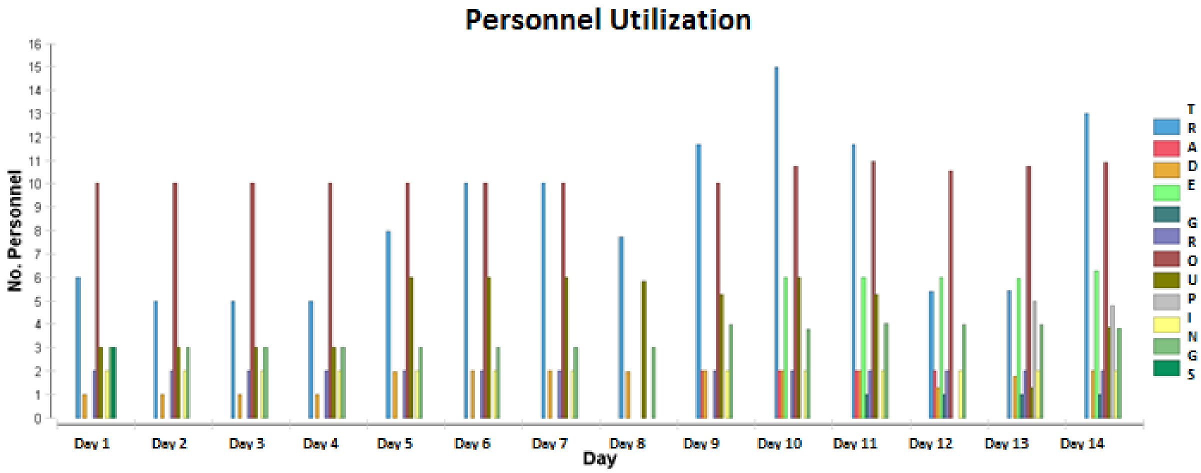

Figure 3. Example of personnel utilization by trade over time

In addition to manning, the number of shifts and days worked in a week are important variables for overall work time. The model supported the production team in assessing any potential timesaving's of moving some of the early steps in the process to seven-day workweeks, from six. The initial results showed that the seven-day workweeks would result in timesavings; however, the production team felt they were not significant enough to offset potential reductions in morale. As a result, the team opted to remain on six-day works weeks, but identified a seven-day workweek as one of the recovery plans available in case of delays or additional unforeseen ship conditions.

Daily uses

Currently, the model supports daily work by providing a visual status before daily morning meetings. This allows the team to assess the progress of the work frequently, and in the future this will result in specific model outputs for trade workers to monitor and remain aware of progress. The morning model runs also help provide production team leaders with insight into required manning for the following week and potential delays.

Post Analysis

The current schedule for work on this carrier will run until the later part of 2014. At the end of the work on this ship, the model will transition to a post analysis mode, where it will support planning of work on the next carrier. During this time the development team will analyze the actual work performed on this carrier, baseline it with the models projected path, and determine improvements to the model and to the process. The production team will then work with planners and supervisors responsible for work on the next carrier to plan the overhaul of that ship.

The model will also support the production team as they perform after action reviews (AARs) of the work on this ship and propose new process' for the next. The model will support them in pre-assessing the new strategies and determining if they are likely to result in timesavings, prior to fully attempting to integrate them into the next schedule.

The model tracking of actual work and delays will also allow the production team a detailed picture of the actual work performed on the ship. This will support a more robust AAR process, and help the team identify areas of weakness, which will be targets for improvement during the next overhaul. The models 'what-if" capability will also allow the production team to suggest fixes, retroactively, for problems they encountered on this ship and go onto to future ships with specific courses of action for similar situations.

Summary

The specialized tank inspection and overhaul simulation model has successfully supported the development team through over 60% of the overhaul process to date. As the work continues the model remains in active use in the ship board environment and continues to provide daily updates on progress. In addition, the archive of actual data continues to grow daily and will support both the current models use as well as use and planning for the following ships. The flexibility of the model has allowed the NNS team to significantly modify work plans and examine outcomes in as little as a few hours, where on previous ships working through the re-planning process could take a week or longer. The data from this analysis supports the decision makers and planners, and allows NNS to keep the customer up-to-date on status and provide confidence in the planned solutions. On future ships the NNS team will continue to explore ways this and other models can support actual overhaul work, as well as exploring the possibility of combining several models to study larger groups of work.

ACKNOWLEDGEMENTS

Mr. Drucker and Mr. Hancock would like to thank Kevan Hutchings, Aris Picardo, and Chris Herman for their help in preparing this paper and for their work on this model.

REFERENCES

Birkler, J. & Chiesa, J. (2002). *Refueling and Complex Overhaul of the USS Nimitz (CVN 68): Lessons for the Future*, Santa Monica, CA: RAND Corporation.

Shaffer, W. R. & Mook, C. (2013). Simulation-Based Adaptive Decision Support in a Shipyard Environment. *Proceedings of 2013 MODSIM World Conference and Expo*.