

An Adaptive Planning Tool for Ship Construction and Material Logistics

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ABSTRACT

Newport News Shipbuilding (NNS) is the sole builder of Navy aircraft carriers in the United States. Constructing and overhauling Navy aircraft carriers is among the most complex work undertaken anywhere in the world. An integral part of these operations is efficient material logistics. Utilization of material laydown and construction areas during the creation and outfitting of new carriers presents a unique challenge for both material logistics personnel and trades workers. As the ship construction process progresses, multiple factors limit the workers ability to maintain the planned schedule of work packages and jobs. Due to the shifting nature of what work is available on any given day, material logistics personnel are constantly asked to update their plans to deliver and store materials onsite. The creation of a tool to help both the trade workers and the material logistics team visualize how shifting work plans impact material laydown strategies. This will reduce touch times and eliminate lost, damaged or underutilized materials. The carrier construction material logistics tool will allow NNS to model the process of creation and outfitting through placement in the dry dock, to demonstrate the feasibility of such a model and demonstrate its benefits. Following successful creation of the initial model, users will be able to see into digital work-packages allowing them to re-plan on the fly and evaluate how these new plans will impact material flow. Users will also be able to determine if material availability, or lack thereof, will require alteration to the work-package construction sequence.

ABOUT THE AUTHORS

Kenyth Campbell is a Modeling and Simulation Analyst at Newport News Shipbuilding. In his role Mr. Campbell is responsible for providing support to multiple projects of differing application areas for NNS. He is also responsible for being the product owner on projects that serve both NNS and outside contractors. In this role Mr. Campbell is tasked with effectively communicating the customers' needs to his development teams to ensure the modeling and simulation projects represent customer interests. Prior to joining NNS Mr. Campbell was a graduate student at Old Dominion University. Mr. Campbell possesses a Master's Degree in International Studies with a concentration and certification in Modeling and Simulation as well as a Bachelor's Degree from Christopher Newport University in Political Science with a minor in Psychology.

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INTRODUCTION

Naval ship construction is an immensely complex logistical activity involving large quantities of highly specialized material, equipment and personnel. All material that ultimately resides in a nuclear powered aircraft carrier (CVN) must be pulled from inventory, staged within a limited footprint and moved to the mechanic's work site along predetermined material paths. Material availability on the right job site at the right time is a key element in maintaining CVN construction schedules. As a new program the FORD class aircraft carrier has many opportunities to improve the material handling, staging and the process of delivering material directly to the tradesman's work site.

The 'Synchronization of CVN Logistics' project will create a simulation based material logistics tool that will allow the user to quantitatively compare different staging and material supply stream scenarios, choosing those that best support the constantly changing requirements as ship construction matures. This tool will be used during construction and outfitting for units on the platen and construction in the dry dock. It will be used by planners and members of management to determine the impact of material delivery on the proposed build strategy.

The framework the tool is built upon will support expansion into the impacts of material warehousing, kitting, and shipping. Equipped with this dynamic simulation tool, the decision makers will be able to sufficiently explore each proposed strategy, resulting in a material logistics system that minimizes unproductive material movement and time off task. The predictability component of this tool will allow the decision makers to rapidly adapt to the dynamics of ship construction, thus ensuring that construction capacity is efficiently utilized. The ability to account for material delivery logistic constraints in a potential plan will greatly increase the probability of successfully completing planned tasks on schedule and within cost.

PROBLEM SPACE

Complex nature of shipbuilding

Due to the complex nature of shipbuilding, NNS has traditionally had to manage lay-down area spatial planning by attempting to handle material as it arrives, planning for the arrival only as ship building contracts begin. Without being able to accurately predict the type and amount of material which will arrive months in advance, the shipyard has to manage material based on historical trends and with only the lay-down space currently available. As new needs for space arise the shipyard is able to address them only after it becomes clear the space is needed. In addition, managing lay-down areas is challenging given the number and size of ships that NNS constructs, material proximity to a given worksite, and the number of units these lay-down areas can hold. The constraints on a lay-down area dictate that it store only the necessary material for a particular unit and only when that unit is ready to be assembled. Additionally, the changing nature of material logistics on ship builds often requires the company to shift material and units to make use of available space, even when these changes may reduce efficiency.

To correlate with material arrival and lay-down areas, the shipyard also faces the risk of manning shortages and partial material deliveries. During the construction of a specific unit it is necessary to have all essential trade workers available. If this cannot be accommodated, the unit under construction build will face delays. An example would include tradesmen "A" "B" and "C" all needing to perform work on the same unit. These three tradesmen have to perform their work sequentially and cannot start on their task before the previous tradesman is done with theirs. If tradesman A is not available for a period of time then tradesmen B and C must sit idle thus wasting man

hours and reducing production efficiency. Additionally it is necessary for all material that is needed to complete a construction phase of a unit to arrive in a timely manner. If a partial material delivery occurs then the unit under construction may sit idle while the rest of the material is being delivered, thus wasting man hours and personnel resources.

Lay-Down footprint management

For the purpose of this project, three primary lay-down areas were identified as vital to ship construction and material logistics. The first of these is a sub assembly platen where prefabricated units of the ship are placed and material is delivered. This sub assembly lay-down area receives the units and supports their outfitting with main structural supports such as walls and decking. Once structural aspects of these prefabricated units are completed they move to the final assembly lay-down area where they are once again paired with material. At the final assembly lay-down area the units are fitted with more complex infrastructure such as structural supports and piping. Here some of the smaller units are also joined together to form larger units that ultimately become a finished part of the ship. The third and final lay-down area is the dry dock. The dry dock is the location in which larger units are fitted together to form the finished ship. This area focuses heavily on piecing the larger units together but also requires that material be delivered and placed in these areas to support the final construction.

To more efficiently manage lay-down area footprints, and to ensure an optimum amount of space is always available, the shipyard required a tool to experiment with potential material arrival schedules, lay-down area capacities and material placement strategies. By testing strategies for material logistics against current lay-down area footprints and multiple potential arrival schedules, the logistics management team can better plan for the future material needs and space allocation. This capability also allows them to predict a space need far enough in advance to perform tradeoff studies between creating a new ship build sequence or re-configuring current build sequences. The tradeoff studies are also better able to indicate how options may impact future material logistic needs and strategies years down the road. By developing several plans in advance the material logistics teams can respond to whichever scenario eventually arises, and have better knowledge of the long term impact of the decision.

THE SOLUTION

Model Structure

From the beginning of the project it was necessary for the model to serve dual functions. The first function being the altering of the current schedule, during the execution phase of ship construction, due to manning shortages and the unavailability of certain materials. If a particular unit cannot be started or completed due to manning or material shortages, then it is necessary to select another unit that can be constructed. In order to avoid the unnecessary and costly price of moving a unit several times and the attendant down time, the model will need to have a continuing list of units that are not only able to be worked but will also have to determine if the necessary manning, material, and space for that unit is available. This strategy will allow the lay-down area logistics team to be prepared if a delay for a specific unit's construction occurs.

The second function of the model is to evaluate space allocation of the lay-down areas as well as material availability. The shipyard now has the means to project the arrival of material many months in advance of actual arrival at the shipyard. The model will look at the material projection reports and determine in what order units should be constructed. To correlate with the material projection, the model must also look at the space available on the lay-down areas and determine the best order in which to place units. Each unit requires a certain square footage to be placed on the lay-down areas including a buffer zone around each unit. The model will need to project the most efficient placement of each unit so that the space on each lay-down has maximum utilization.

The structure of the model began with an examination of how material is placed once it is delivered to the lay-down areas. Each unit that is placed on a lay-down area is accompanied by an invisible buffer zone that allows for material to be stored around each unit without affecting the work of the neighboring units. To this end it was necessary to not only have the model look at the placement of the material but also the placement of the units themselves. Each unit requires a certain square footage on the lay-down areas and no two units are the same. In order for a unit to be efficiently placed on the lay-down areas there must not only be room to accommodate the unit itself but also the buffer zone that is required for each unit. This addition of space allocation for units was a large expansion to the

model and required large amounts of data as well as knowledge of all the units that could potentially be placed on any of the lay-down areas.

With the addition of the unit placement within the model the methods present in the model structure changed drastically. To begin, the model would need to look at the current units in all of the three lay-down areas and determine when they were to be completed, based on an estimated date. Once a unit is completed, it is then the model's task is to look at the square footage of space available after the completed unit is moved. The model will then look at all available units that can now fill the vacant space and still accommodate the buffer zone required for each unit. The model also needs to fill the vacant space precisely so that excess space is minimized. The model logic structure is such that the model picks the units that most precisely fill the vacant space on the lay-down areas first. The selected unit is then used to determine what type of material is used to complete its construction within its projected timeframe. The model then looks at the material arrival schedule to determine if the material needed to construct this particular unit will be available during the projected start/finished dates. If the material will be available the model will place this particular unit in the vacant space on the lay-down area. If the material will not be available, the model moves on to the next unit that fills the vacant space. If a unit that precisely fills the vacant space is not available then the model will move to a smaller unit that does not maximize the utility of the space available but is the next best option. This process is continued until the model identifies a unit that can fit in the vacant space, maximize the space utilization as much as possible, and will have the necessary material available for the units projected start/finish dates. The model receives weekly updates on the actual progress of all the units on the lay-down areas so that it can account for delays or units that are ahead of schedule.

Once a unit is successfully placed on the lay-down area, it is necessary for the model to account for the amount of material that will need to be delivered to a particular unit and the most efficient space to place that material on the lay-down area. The model must do these calculations using the rule that material can only be placed under the unit itself or within the buffer zone for that unit. Material is commonly delivered to the lay-down areas via trucks or forklifts and thus the model must account for the limits of this equipment. A truck and/or forklift can only place the material so far under a unit, as the units are often elevated only enough to allow for work to be completed on the underside of the unit. Accordingly, the model follows a custom "doughnut" or perimeter logic. If all of the reachable space under a unit is occupied with material the model will elect to place the material in the buffer zone. This allows the material to be close to the unit but does not interfere with the work to be completed on the surrounding units.

The model also has the ability to be used during the planning phase of ship construction. When NNS is planning its next CVN build the model can be used to look at the most efficient locations to place units based on material availability and the space required to place that unit. For this aspect of the model, the lay-down areas are cleared of all units and material, within the model, and the model starts with a clean slate of space. The model then uses a "Tetris" algorithm to place units, maximizing the utility of the space on the lay-down areas. The model also takes into account the availability of material and the projection on when it will arrive. If material is not projected to be available for a particular unit then it will not be placed on the lay-down areas by the model until the material is available, but only if the required space is available as well.

Data Collection and Formatting

The data collection for the model begins with the material itself. Each unit in the model contains a certain number of work packages required to complete that unit, each one of these work packages contains a list of material that will need to be delivered to the lay-down areas. The development team thus had to gather a list of all work packages necessary to complete a CVN. Once this was done the development team broke out each work package to determine the list of materials that were needed for each. The material listed for each work package is transported to the lay-down areas on pallets. To accommodate the spatial aspect of the model it was necessary for the development team to determine the dimensions of the standard pallets that are used to carry the material as well as the amount of material that can be placed on these pallets. With this first step complete the development team was able to determine that the placement of each unit on the lay-down areas would need to be tracked as well.

The development team had already determined the number of units that were required to complete CVN construction and the material that was required to construct them, but further data was needed. If the model was going to track spatial logistics of the units as well as the material the unit data would need to be more robust. The development team thus had to collect the footprint measurements for all of the units required for a CVN

construction. Each unit has a length and width measurement associated with them, thus the team was able to easily collect this data. The units also have a vertical height measurement associated with them, however this data was not used for this phase of the model because the units are stored outside. Storing the units outside allows for the vertical height to be much larger than if they were stored in a building and thus was not an issue during this phase of the project. As a side note, the model can be adapted to include the vertical height measurement if NNS did place units inside of buildings in the future.

A third piece of data that was necessary for the model was the purposed build schedule for the current CVN hull. This build schedule included not only the amount of time the units were projected to be placed on the lay-down areas but also the amount of time it would take for one work package to be completed. The model will use this information to determine when space is available for a new unit to be placed on the lay-down area as well as when it will move from sub assembly to assembly to the dry dock. Along with the unit data, it was also necessary to collect the start/finish completion dates for each work package. These start/finish dates for each work package will allow the model to project when a pallet is placed near a unit on the lay-down area and when it will leave. This will allow the model to determine when it can place material under the unit or when it will need to place material in the buffer zone associated with a unit.

A hidden problem arose during the data collection process. While all of the necessary data was available and able to be collected, it was determined that not only the CVN units and material being looked at by the model would need to be collected but rather all of the ships and their material being constructed by NNS at one time would need to be collected. Since NNS constructs multiple ships and ship types at one time, and these ships all have units placed on the lay-down areas simultaneously, all of these units and their material would have to be accounted for in the model. The main focus of this model was to look at new carrier construction, however NNS constructs submarines, overhauls carriers, and decommissions carriers. Though new carrier construction has the largest number of units and material placed on the lay-down areas, it is possible that these areas would be used for units and materials of other ships. Thus it was necessary to collect the data for these other ships as well. The development team had to collect the dimensions of these other units and materials as well as their projected start/finish dates so that it could be accounted for in the model calculations.

Future Use

Following the completion of the model, the team will begin utilization to support the analysis of material logistics and spatial utilization of the lay-down areas. The logistics team will be able to experiment with the model and look at three different aspects through experimentation. The first of these will be the placement of units on the lay-down areas as the CVN build sequence progresses. Experimentation with the model will help the logistics team determine which units could be placed in a vacant space on the lay-down area based on a unit's size and material availability. In the past construction supervisors would have to dig through many units and their work packages to determine if a unit was able to be constructed. After they have chosen a unit they would have to physically visit the lay-down area to see if enough space was available to accommodate the unit they had chosen. The model will allow the construction supervisors to only view the units that will fit in a vacant space and will also rule out the units for which material will not be available. This model output will greatly reduce the time and effort a construction supervisor will have to use in order to select the next unit that should be worked. Reducing these two key factors will help NNS stay on schedule and help reduce the cost of the CVN construction. Figure 1 below shows an example output of how units will be placed in the model and how the model focuses on spatial utilization.



Figure 1: Spatial Utilization of Lay-Down Areas

Figure 2 below shows the logistics team the placement of the material around and underneath the unit. This model output will allow the user, such as a construction supervisor, to determine if all the material for a particular unit is available. This feature of model will be used for the construction of the current CVN since the process is already underway. If the model demonstrates that material for a certain unit will not be available when needed then a construction supervisor can move his tradesmen to a different unit minimizing the amount of man hours that are lost due to material availability. This aspect of the model will also be useful for future CVN construction in determining if all of the material that is supposed to be stored under/around a unit will fit based on the material needs schedule. If there are going to be too many pallets stored under/around a certain unit then the construction supervisor could know in advance and make the necessary arrangements to correct this problem, allocating a larger buffer zone around the unit for example.

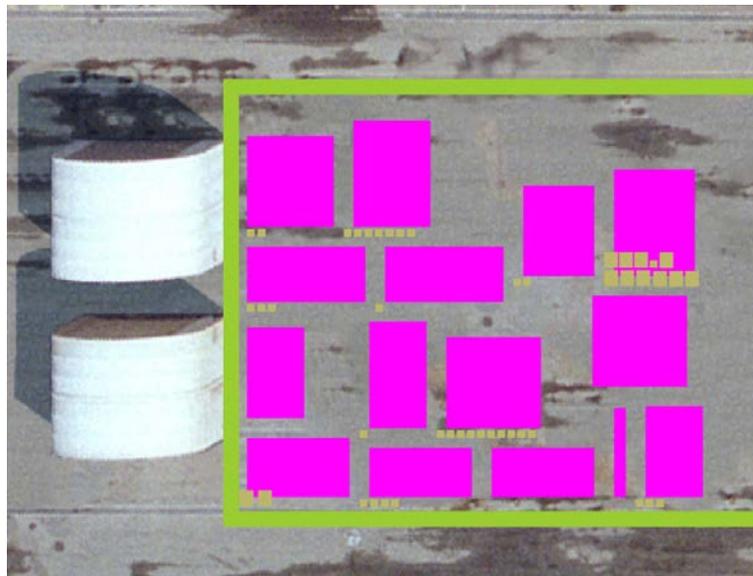


Figure 2: Units with Material Placement

Figure 3 below provides a good example for the final output aspect of the model and how it can be used for future builds. NNS has never had the ability to clear the lay-down areas completely of material and determine the best build sequence from scratch. The model will allow planners to do just this and start with clean lay-down areas and develop a more stream line build sequence that will efficiently use the space that is available. This aspect of the model output not only generates a build sequence based on space utilization and material availability but also gives the user the ability to manually drag and drop this unit within the certain lay-down areas. If the user drops the unit in

a space that is not big enough for the unit and its companion buffer zone then the unit will change color, in Figure 4 below it will change to a red color, to represent a size conflict letting the user know that this unit cannot be placed there.



Figure 3: Lay-Down Area Cleared of Material/Units

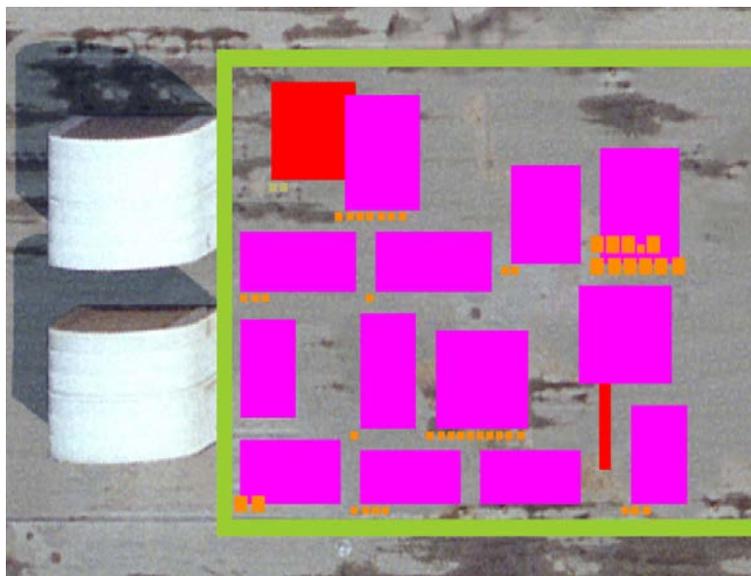


Figure 4: Unit Conflict when Manually Moved

SUMMARY

To handle the complex nature of material logistics and spatial allocation in a shipbuilding environment, NNS developed an adaptive planning tool for ship construction management. The tool allows the logistics team to analyze potential material arrival schedules and lay-down area capacities against the current build sequence to identify ideal construction strategies. The tool also allows them to respond rapidly to any unpredicted changes to a ship's build strategy, as well as determine which build strategies fit within the current lay-down area capacities and future material availability needs. The tool is on track to support the team in examining new and improved material logistics strategies during the third quarter of this year. The tool will help with decision making about potential new strategies and their feasibility, and would allow NNS to allocate enough space on the lay-down areas to support its

current plan and potential flex needs. In the future the tool will grow to include the movement of material from warehouses at NNS to job sites, both indoors and outside, and hopefully its eventual incorporation into the entire CVN planning and building strategy. Even though the project is not yet complete it has already drawn attention from NNS and the potential for expansion to the VIRGINIA-class submarine and refueling and complex overhaul (RCOH) programs is being explored. The greater fidelity to follow material and units through their movements on the lay-down areas will further improve the logistics team's ability to plan and manage their space and material by seeing further down build sequence.

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