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USING SIMULATION TO EVALUATE CARGO SHIP DESIGN ON THE LPD17 PROGRAM

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ABSTRACT

As part of the design of the next generation Naval Amphibious Transport Dock Ship (LPD17), simulation was used to evaluate the arrangement and flow of cargo on the ship and to integrate material flow concepts with the overall design requirements (see Figure 1). The simulation model evaluated specific cargo load out scenarios to determine if the proposed material handling systems would satisfy specific mission criteria. The simulation was developed in 3D using a common database of CAD geometry to not only evaluate the throughput and utilization of proposed systems but also to verify that those systems could operate within the confined spaces of cargo ships. The model considered factors such as cargo type and arrangement, forklift speed, turning radius, elevator size, and elevator speed. The placement of cargo was driven from external files and a rule set was developed to allow for the automatic generation of an unload sequence. This paper will focus on the construction of the model, its data file flexibility, and the results of the missions evaluated during the project. It will also discuss the role 3D simulation played in validating this model and communicating specific simulation results.

1 PROJECT OBJECTIVES

This project had three main objectives, 1) Determine if the ship design could meet the specific mission criteria defined by the United States Navy, 2) Provide a method for visualizing the process of unloading the cargo, 3) Provide a model that could be easily changed to evaluate future mission requirements.

Cargo ships for the United States Navy are required to re-supply battle groups at sea under a variety of different mission criteria. This simulation was used to evaluate the overall design and cargo arrangement on the LPD17 under several specific mission criteria. These five missions were specifically chosen to emulate the tasks that the ship would be asked to perform once it was in service. The prime method for evaluating the design of the ship and arrangement of the cargo was the time required for the mission to be completed and the manpower required to accomplish each task.

In order to effectively design the ship and ensure that these mission criteria were met, the ship was designed in 3 dimensional CAD software. This meant that the simulation analysts needed to interact with the ship designers on a regular basis to make sure the simulation reflected the most

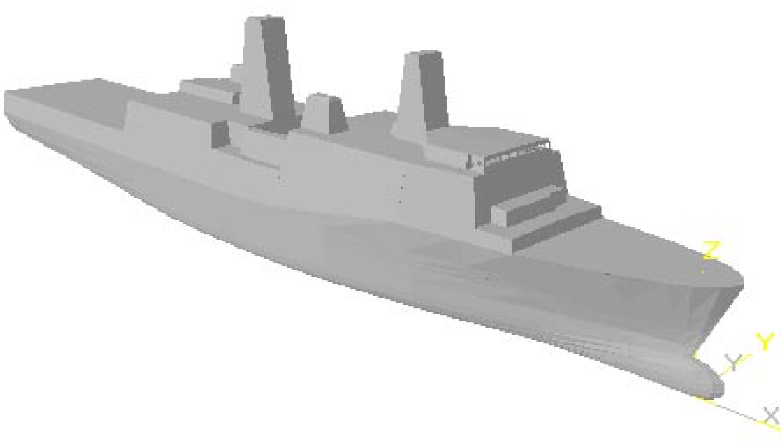

Figure 1: Next Generation Naval Transport Dock Ship (LPD17)

current physical designs. In addition to the discrete event simulation models discussed in this paper, detailed kinematic simulations were built to validate that it was physically plausible to access the cargo in the proposed arrangement. The discrete event simulation model was used to tie together the various kinematic models so they could be visualized in a single simulation environment.

The final objective was to allow rapid changes to the model input. The model needed to be driven from data files that could be easily changed as the ship design and mission criteria were modified. These modifications fell into two major categories, changes to the physical parameters of the ship/cargo and changes to the input parameters such as cargo arrangement, forklift speed, elevator speed, etc.

2 SELECTING THE SIMULATION SOFTWARE

The simulation software chosen to build the model was QUEST from Delmia (formerly Deneb Robotics). QUEST was chosen because it is a highly visual simulation product and its architecture supports sharing data with CAD packages and other simulation packages from Deneb.

The key factor in the decision was the distributed nature of the QUEST data model. QUEST simulation models are not saved in a single file. Instead, the model file contains a series of file pointers that import the most current version of graphical or logical data each time the model is edited. This automatically keeps the model current and greatly reduces the amount of redundant data in the project. Consider large files that are used by the simulation. In QUEST, a single copy of the file can be stored and accessed by many different models whereas traditional simulation model architectures would save a copy of this file with each version of the model even if the large files were identical from one model to another.

3 MODEL OVERVIEW

The model includes all of the cargo handling tasks for the LPD17 ship. For the purposes of the model, three decks of the ship are relevant, the Cargo Ammunition Magazines (CAMs), the Main Vehicle Deck (MVD), and the Main Deck (MD). There are three CAMs that contain cargo and each one has an elevator that is dedicated to transporting cargo from the CAM to either the Main Vehicle Deck or the Main Deck. The model contains seven forklifts (see Figure 2). Each one has its own parameters for speed, turning radius, and capacity. The model ends once the cargo is dropped off by the station where it is sent to an adjacent ship by zip line or helicopter.

The model is designed to evaluate the ‘strike-up’ of cargo to other ships. With this in mind, the model is initialized from an external file with the proposed cargo arrangement. This external file dictates the position and graphical representation for each piece of cargo.

Figure 2: Rough Terrain Forklift

Once the cargo is loaded, the model goes through a series of missions to evaluate the wide variety of tasks that the ship will be asked to meet. For each mission, a subset of cargo, known as a category, is selected for offloading. Due to the tight space constraints on the ship, cargo is often buried in the cargo hold. The model uses a shortest distance algorithm and knowledge of the size of the elevator to determine the best order to unload the cargo. If cargo must be moved to access a buried pallet, a default time is taken to move the material and then the cargo is staged in front of the elevator.

The elevators in each CAM can hold from one to four pieces of cargo. The model tracks the weight and linear length of each part to determine when the elevator is full. Once the cargo arrives at the Main Deck or the Main Vehicle Deck, it is unloaded by another forklift and taken to a station for shipping. In some cases, it is necessary for two forklifts to be involved in the transportation of cargo to its final destination. This is due to tight corridors and the large size of specific forklifts.

4 MODEL FLEXIBILITY

The model is driven by six text files that contain all of the information on the operation of the model. These data files are all text based and can be selected by the user each time the model is executed. This allows the model to be used for any ship design and configuration that has three CAMs and two destination decks for offloading cargo to adjacent ships.

5 MODEL VALIDATION

The two main methods used to validate the model were meetings with naval experts and the use of deterministic data. The model was developed with input from naval experts over a period of three months. During the validation phases of the project, the pickup, setdown, and retrieval times for all of the cargo were set to deterministic values. This allowed the total time for each category to be computed. The model output also included time stamped event files that could be used to walk through the model on a step-by-step basis. Once the model was validated, distributions were used for all operations that involved human intervention. The run results shown were a summary of 10 replications using different random number streams.

6 MISSION RESULTS

There were five missions defined as part of this project. Each mission had a scheduled start time based on the start of the model. Table 1 defines these missions

The simulation model was used as a tool to help with the cargo arrangement. Initial simulation runs did not meet the time constraints defined by the naval engineers. By monitoring the amount of time spent on non-value added cargo moves, an arrangement that met all of the criteria was developed. Category B and C cargo were concurrently unloaded from two separate CAMs to evaluate the unloading conflict that was created on the Main Deck. The simulation showed the forklift to be the bottleneck of the system during Category B/C. In all other instances, the elevators were the bottleneck of the system. Category E and F cargo also occur at the same time but they originate in different holds and terminate on different decks.

One of the other concerns the model addressed was the training level of the individuals performing the tasks. It was believed that the elevators would be the bottleneck of the system. To evaluate the impact of manual cycle time variations on the system, the manual tasks were given uniform distributions of 15% and 25% to see the effect it would have on the overall mission timeline. Table 2 below shows the variation for each cargo category under the baseline, 15% and 25% scenarios. While there was up to a 6% variance on the maximum times for handling cargo, the overall times for the individual missions did not vary.

7 THE ROLE OF 3D SIMULATION

There were three main areas of the project that were greatly enhanced by the use of 3D simulation, Model Validation, Model Accuracy, and Integration with Other Modeling Efforts.

7.1 Model Validation

The project involved dealing with a diverse team that ranged from design engineers to high-ranking officers in the United States Navy. Having a common point of reference to see the model in action was an excellent way to ensure that everyone was on the same page. The fidelity of the graphics made everyone confident that their understanding of the model's operation was correct. The model made it possible to watch the entire several-hour mission unfold in a matter of minutes. Each area of the mission that was considered problematic could be analyzed slowly and the design alternatives considered were reviewed. By the end of the project, all parties involved were confident in the results provided by the model and all assumptions were well understood.

Table 1: Baseline Mission Completion Times

Cargo	# of Cargo	Start Time	Allotted Time	Completion Time
Category A	14	0:00	60 min	39 +/- 3 min
Category B/C	27	1:00	60 min	32 +/- 1.2 min
Category D	12	1:30	60 min	18 +/-3 min
Category E	16	3:30	30 min	29 +/- 1.8 min
Category F	1	3:40	20 min	2.1 +/- .8 min

Table 2: Study Findings

Cargo Processing		**Mission Category**					
Times (Mins)		**A**	**B**	**C**	**D**	**E**	**F**
Baseline	Average	8.6	7.9	3.0	8.2	11.1	2.1
	Minimum	5.9	2.1	2.1	2.1	2.2	2.1
	Maximum	14.5	16.1	3.3	13.0	18.8	2.1
15%	Average	8.64	7.87	3.01	8.28	11.09	2.10
	Minimum	5.57	2.01	1.96	1.96	2.14	2.01
	Maximum	14.97	16.30	3.37	16.04	21.91	2.19
25%	Average	8.64	7.90	3.00	8.33	11.09	2.12
	Minimum	5.38	1.97	1.88	1.88	2.08	1.97
	Maximum	15.30	16.39	3.40	16.43	21.89	2.26

7.2 Model Accuracy

The model uses space, distance, and the speed of the forklifts to determine the median time for the individual tasks. By using a 3D simulation package, the project avoided potential mismatches in the input data between the true distances traveled and distances typed into the model. Also, since the cargo arrangement is shown in 3D and to scale in the model, we are assured that the arrangement is valid and feasible in the real world. Many times during the modeling process, overlapping cargo was observed in one of the CAMs and adjustments had to be made in the proposed cargo arrangement.

7.3 Integration with Other Modeling Efforts

In addition to discrete event models, this program also involved detailed kinematic simulation for the loading and unloading of all cargo into its appropriate elevator. While these simulations focused on clearance issues and recommending the appropriate forklifts for each task, the fact that the same geometry engine was used for all models made the QUEST model more graphically accurate with no work on the part of the simulation analyst.

8 CONCLUSIONS

Using simulation to provide a framework for design evaluation and improvement is an excellent way to organize and motivate a disparate team of engineers toward a common goal. The high level of visualization encourages input from everyone on the team and gets buy-in to the model's value early on in the project. In the case of this program, the organization and utilization of the proposed CAMs was improved upon to meet the stated mission criteria. It is the belief of the authors that future simulation programs for the United States Navy will only increase the level of visualization in this type of modeling.

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