Developing a Manufacturing Simulation as a Deliverable Product

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ABSTRACT

Typically, commercially available modeling and simulation products are tools that allow Modeling and Simulation (M&S) practitioners to construct, run, and analyze simulations. These products are useful only to professionals in the M&S field who know how to properly construct a model and generate the required analysis. This necessitates the use of commercial products in conjunction with a professional to sell modeling and simulation as a service. In certain situations, customers may not want to purchase a service, but a tool that they can use themselves. This paper presents an approach to M&S which results in a standalone tool. The tool in this example was developed specifically for use in a manufacturing setting, not by the M&S professional, but by the people in charge of planning and executing the work. By shaping the inputs and the analysis to align with the customer's knowledge base, a non-M&S user can complete simulations with little or no assistance from the experts that developed the model.

ABOUT THE AUTHOR

Christopher Mook began his career at Newport News Shipbuilding in 2007 as a structural designer. In 2009 he joined the Apprentice School as a ship fitter and spent 2 years on the construction of aircraft carriers and submarines. In 2011, he was selected into an advanced apprenticeship working in Modeling and Simulation and has assisted in the development of several models for shipyard programs. He is currently in the final term of his apprenticeship and is attending ODU working towards a B.S in computer engineering.

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Introduction to the Problem

Newport News Shipbuilding (NNS) works in conjunction with Electric Boat (EB) to construct nuclear powered submarines for the U.S. Navy. This means that much of the work in the construction is shared amongst the two shipyards. Part of the work that was shared was the development of the weapons cradle modules that are used to move various armaments throughout the submarine. In 2013 it was decided that due to the nature of this work, NNS would manufacture all of the weapons cradles. Since the work in the construction of the cradles was originally split between the two yards, the number of cradles that would have to be produced by NNS would be doubling. This meant that a change needed to be made in the process for the creation of the cradles. The construction management team decided that a model would be helpful in the decision making for changing the process.

The modeling and simulation group was approached and asked to develop a model. Typically when developing a model/simulation, the customer describes the problem and the modeling and simulation professionals analyze the problem, collect the pertinent data, develop a model/simulation and deliver the results to the customer. In some cases with larger models, a modeling and simulation practitioner is sent to work with the customer and run and update the model on a regular basis. When the task was given to the modeling and simulation group to develop a model for this manufacturing process, the request was made to deliver the model itself and not an analysis of simulated data. The customer wanted a model that would be useable by the construction managers and the planners involved with the project. This meant that a new approach would have to be taken to ensure that the model being developed would be easily understood by the customers and not just the modeling and simulation practitioners.

Rethinking the Input

In the development of most simulation models, once the data is collected, it can be converted into a form that is useful for feeding the model being developed. When developing a model to be used by the customer, the customer's understanding of the processes must be considered when developing the input data for the model. This meant understanding the changes the customer wanted to test for implementation and allowing for these pieces of the process to be easily altered. Typically, when developing a simulation, the practitioner wants the ability to adjust every piece of input to the model to allow for the ability to test every scenario necessary. Expanding the input to this level could overwhelm the customer and lead to model training becoming too large of a task and losing the customer's focus and ultimately their business.

Instead of approaching the customer and learning the problem that was attempting to be solved, the modeling and simulation team also had to figure out what the construction team believed to be the viable options in solving the problem. These became the solutions that the construction team wanted to test and allowed for simplification of the input to address these solutions specifically. In addition to limiting the input to these specific solutions, the team also had to develop a way to implement these solutions in the model that would be easy for the customer to understand. To accomplish this task, construction team was asked for the metrics and tracking data that they currently used for their processes. This allowed the modeling and simulation team to approach the problem using the same terms and data that the customer was already familiar with, thus reducing the learning curve significantly.

The other large piece to tackle in the input was how to ensure that the model reflected real time statuses of work. In the past, modeling and simulation practitioners have been deployed with a model to work alongside the construction teams and not only run the model, but collect data and work complete to ensure that the simulation reflected the current status of work. The construction team that requested this model already had jobs to do and could not spend a significant amount of time inputting process data that the typical models require to stay up to date. The team decided that the best approach to take would be to allow the customer to input current status at the time of the model run. Instead of tracking all work completed and inputting all of the data into the model, the customer could simply input the current status of each workstation and start the simulation from there. Because the construction team already had their own metrics and data they tracked, there was no need for the redundancy of having to input all of that data twice. This allowed the customer to continue tracking as they always had but also to simulate the process going forward from the current status.

Understanding the Simulation Results

After a model has been constructed, typically a modeling and simulation practitioner, acting in the role of an analyst, will run the model many times and comb through the data to answer the questions of the customer. When deploying a model for a customer to run, the customer, not being a modeling and simulation practitioner, cannot be expected to examine raw data and make conclusions. With this in mind, the modeling and simulation team had to devise a way for the model to output the data in a format that was not only easy to understand, but also useful in answering the questions that drove the customer to run the simulation in the first place.

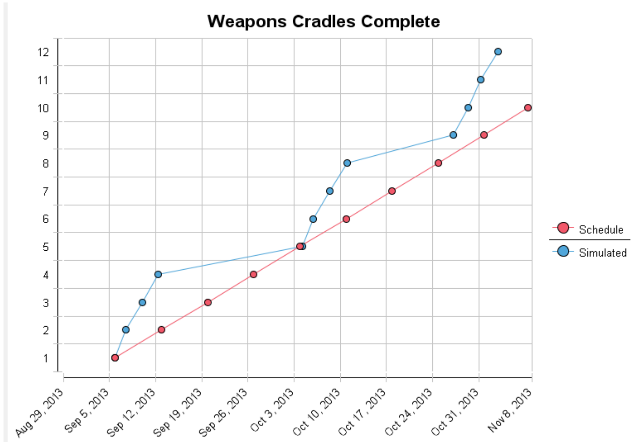

Figure 1: Sample Output Chart

While the weapons cradle model was being constructed, the customers were interviewed multiple times through the process to determine the information that would be useful for improving their work. It was also important to know what information they would need to compare actual results against to verify that the changes that were being made were comparable to what the simulation predicted. Once the requirements had been verified, the tool was able to generate charts that would not only portray the data in a way that the customer could understand, but also aggregate the data across multiple runs to show trends. These charts were also developed in a way that reflected the metrics that the customers currently used to manage their processes. Translating the raw data into the business language of the user makes the tool useful to anyone involved without having knowledge of modeling and simulation.

Challenges of Delivering a Modeling and Simulation Product

Anytime a tool is put into the hands of a user that is not qualified to use it, there is an opportunity for misuse of the tool. When developing model or simulation to deploy as a product, it became very evident through discussions with the customers that training would be necessary. An important aspect in the development of the tool became developing it in a way that the user would not have to be trained significantly as to how to operate the tool so more time could be spent on training the user on how the tool should be used. One of the most important aspects of simulation is repetition, and there is a strong tendency of non-modeling and simulation practitioners to look at the data from a single run and try and make decisions based on the data. If a tool is easy to use and operate for the standard computer user, more time can be spent reinforcing the concepts of good modeling and simulation technique. This was addressed by not just handing the product to the customer, but developing an in depth user guide to deliver with the model, along with holding an initial training to ensure the instructions in the user guide were clear and the customer was able to understand the process of running a simulation.

Another major challenge that is on-going in the delivering of a model is customer follow-up. Typically, a customer would request a simulation and the customer would be involved, along with a modeling and simulation practitioner. In the case of delivering a model, once the model is complete, the experts are not in place to walk the customer through the use of the model on a day to day basis. While attempts are made to stay in contact and make sure that the model is being used appropriately, it is challenging to ensure that the customer completely understood the training and is using the model in a way which does not misrepresent the results of the simulation. Having a point of contact that will be available to the customer whenever a question arises and to periodically contact and review the simulation work that is being performed should alleviate the most of the customer follow up concerns.

Deliverable Product

After a series of development cycles and reviews, the weapons cradle model was ready for delivery to the customer. The input sheet contained the data in a format that would be easy for the customer to understand, but still maintain several variables that can be changed for a simulation.

Department	Total Quantity	FirstShiftManning	Type	Notes
		Quantity	Personnel or Equipment	
Fitter	20	20	Personnel	*Fitters*
Welder	20	20	Personnel	*Welders*
Inspector	2	2	Personnel	*Inspectors*
Fixture	4	N/A	Equipment	*Fixture used during Stress Relief*

Figure 2: Resources

One of the most important aspects to solving the problem of how to double the output of the cradle manufacturing was how to properly allocate resources. In the input sheet, the user is able to very simply change the number of employees and fixtures, including how many employees will be available for each shift. The model is able to take that data and restrict work when the resources for a particular part of the process are unavailable.

Activity	Process Time	Time Unit	Department	Manning
Fit parts for endblock assembly	fixed(10)	Hour	Fitter	1
Weld parts for endblock assembly	triangular(5,6,7)	Hour	Welder	1
Fit gussets onto sidewalls	triangular(12,18,24)	Hour	Fitter	2
Weld gussets onto sidewalls	fixed(12)	Hour	Welder	2
Fit endplates onto baseplate	triangular(3,4,5)	Hour	Fitter	1
Weld endplates onto baseplate	fixed(7)	Hour	Welder	1

Figure 3: Process Resource Allocation

Another aspect relating to resources is how much needs to be allocated to each piece of the process. The customer wanted the ability to change the number of resources that would be allocated to a specific job and then change the amount of time associated with that job to reflect an increase or decrease in the resources.

This became the most difficult part of customer understanding due to the necessity of capturing variability in the process. The team chose to use triangular and fixed distributions to establish these times and these distributions seemed to be the easiest for the customers to understand. The most difficult part was getting the customer to understand the nature of the triangular distribution. While most people understand the idea of averages, some aren't as clear on the concept of mean. This was overcome by avoiding the term mean completely and instead referring to the first number as "the earliest you could finish the job", the last as "the longest it could possibly take you to finish the job", and finally the mean, or middle number, was described as "this is how long it would take you most of the time." With this simple understanding of distributions, the customer had little trouble understanding how to manipulate this data to test solutions to their manufacturing challenges.

Cradle ID	Desired Completion Date
WC1	7/30/2013
WC2	8/6/2013
WC3	8/14/2013
WC4	8/22/2013
WC5	8/30/2013
WC6	9/7/2013
WC7	9/15/2013
WC8	9/23/2013
WC9	10/1/2013
WC10	10/9/2013
WC11	10/17/2013
WC12	10/25/2013

Figure 4: Schedule

Another important piece to the input was finding a way for the customer to compare the results of the simulation to the required manufacturing outputs. By providing a sheet where the customer could simply input the scheduled output dates, the model was able to pass through the information and compare the average over multiple runs to the scheduled output. This provides the customer with easy to read feedback from the input changes that will quickly identify how the simulated output relates to the required schedule.

Along with an easy to understand model input, the user interaction with the model also needed to be fairly straight forward and simple. The customer needed to have a simple way to perform multiple runs and an easy way to access charts and output once a simulation was complete. A relatively straight forward graphical user interface, along with a detailed user manual was put into place to make the customer interaction with the model as straightforward as possible. With the interface, the customer can select the number of runs that need to be performed and simply hit the play button. The progress of each run, as well as the progress of the set is displayed for the customer to watch as the simulation completes.

As the simulation runs, data from the multiple runs is stored into a database. This allows the data to be aggregated and used to build charts so the customer can easily understand the results of the simulation. The customer has access to these charts through a menu on the interface. The charts are developed from the data at the time they are selected from the menu, so the data that drives the charts always includes the latest data added to the database.

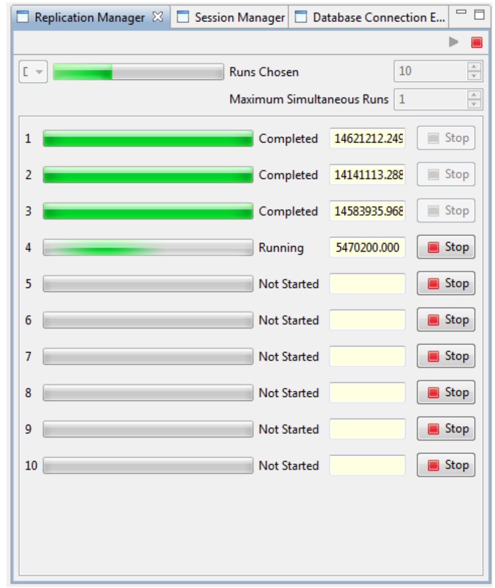

Figure 5: Multiple Run Interface

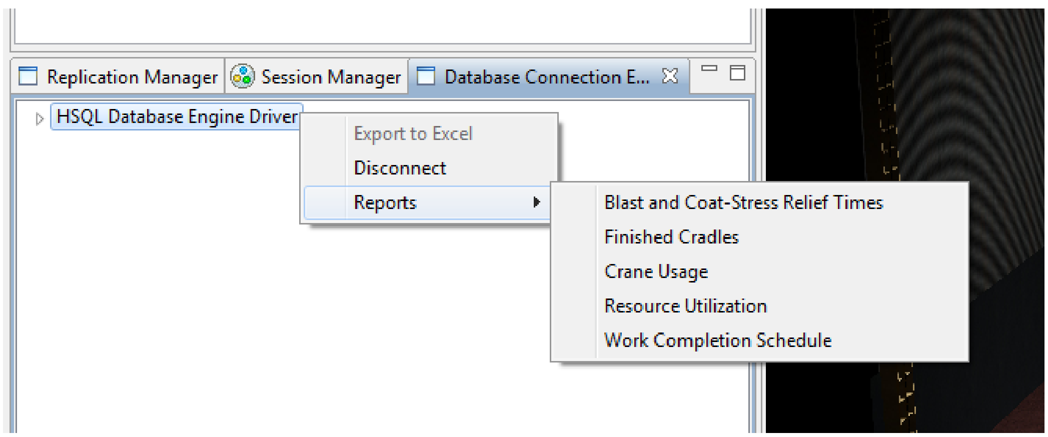

Figure 6: Chart Interface

Model Delivery

The model has been delivered to the customer and training has been conducted on how to use the model appropriately. The training lasted an hour and was conducted with three potential users of the model. While the user interface is pretty straight forward and easy to understand, a good portion of the time was spent on the importance of good practice in modeling and simulation. It was necessary for the customer to understand the importance of variability in simulation and to also understand that it was imperative that multiple simulations runs were necessary to ensure the results they were receiving were not outliers. The customer seemed excited to receive the model and was looking forward to using it to improve and predict the outcomes of changes to their process. Efforts are currently being made to follow up and verify that the model is being used appropriately and the data from the simulation is effective in helping the customer to better understand how changes to the process will affect their production output.

Summary

Developing a modeling and simulation tool for use by a non-practitioner required a shift in thinking from the way a simulation service is typically developed. Having the customer involved early and often in the process proved to be essential in ensuring the model not only answered the necessary questions, but also was usable by the customer. Through the adaptation of the input and output of the model to suit the language the customer uses in their interactions with the process, the customer was able to make changes and understand how the changes affected the process very easily. Combined with a simple user interface and lessons on good modeling and simulation practices, the delivered model could be put into service immediately without a significant period of training.

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