Title: Using Isight Simulation Automation Tools to Reduce the Cycle Time for Ship Structural Analysis Processes

Authors: **Name: Sean Murphy, P.E. (Primary Contact)**
Allyn Boday
Company: Huntington Ingalls Industries
Address: PO Box 149
M/S 1014-06
Pascagoula, MS 39568

Phone: 228-935-2284
Fax: 228-933-8016
E-Mail: sean.murphy@hii-ingalls.com

ABSTRACT

Huntington Ingalls Industries – Ingalls Shipbuilding (HII) is required to perform several different types of structural shock and vibration analyses under the terms of US Navy shipbuilding contracts. Some of these required analyses include whipping, longitudinal strength, linearized stress, pipe shock test, bolt stress, equipment foundation, pipe hanger stress, and ship weight analysis. Historically, these analyses were run interactively by Ingalls Shipbuilding (i.e., without the benefit of Simulation Automation). Under a multi-year National Shipbuilding Research Program (NSRP) sponsored project, Ingalls Shipbuilding and Dassault Sytemes Simulia Corporation collaborated to apply the Isight simulation automation tools to several of the ship shock and vibration analysis processes. Ingalls Shipbuilding experienced substantial man-hour savings when using a prototype simulation automation model to execute any of the given analyses. Hundreds, or even thousands, of man-hours of analysis time are predicted to be saved when considering the labor savings for any individual analysis must be multiplied by the total quantity of that type of analysis that must be performed per ship hull. The first section of this paper presents an overview of some of the ship structural analyses, the simulation automation Isight models created, and a summary of the predicted man-hour reductions. The second section of the paper discusses how Isight is predicted to enable meeting schedule demands. It commonly occurs that 100 equipment foundation analyses, requiring 24 man-hours per analysis, are requested to be executed within two weeks. Using Isight simulation automation tools is predicted to make it more realistic to meet this type of schedule requirement.

SHIP DESIGN AND ANALYSES

Ship design and analysis is an iterative process requiring interaction among different disciplines involved in the design at the various stages of the design cycle, from the early concept to the final detailing stages. The typical ship design process starts with a conceptual design that is initiated by creating a simple model. The conceptual model evolves into a preliminary model through numerous iterations involving different analysis processes leading to a refined model after final details based on manufacturing and assembly processes are incorporated. This process follows a design spiral, as the requirements from each discipline are addressed sequentially in the design process, for each iteration.

The present process involves the use of various domain-specific engineering tools. At the conceptual stage these tools are often limited to ship configuration and hull surface definition. On the other hand, at the detailed engineering stage the high fidelity numerical analysis process is very complex and time consuming. Hydrodynamic, acoustic, and structural analyses are highly coupled and detailed structural finite element mesh (FEM) models are manually built for each vehicle configuration. Different specialized software tools are needed for each analysis. Significant effort must be expended manually to overcome the shortcomings of the 3D Computer-Aided Design (CAD) models when creating the mesh for the various analysis solvers.

In early 2007 General Dynamics/Electric Boat Corporation (EB), Huntington Ingalls Industries-

Ingalls Shipbuilding, Dassault Systémes Simulia Corporation, and Product Data Services Corp. (PDSC) formed a team to define, demonstrate, and provide examples of approaches to reduce the time and cost of creating computational analysis models for shock (and other) simulations. This team conducted two **National Shipbuilding Research Program (NSRP)** projects entitled ***Improved Methods for the Generation of Full-Ship Simulation/Analysis Models 1 & 2 (M&S)***, (References 1 & 2). In particular, the focus is on very large models often representing full-scale ships and Naval vessels. A primary motivation for this work was that of facilitating and performing more analytical simulations in lieu of very expensive, and environment unfriendly, full ship shock trials or tests. Other benefits include: performing Computer-Aided Engineering (CAE) analysis earlier in the overall process, providing systematic data handling and process flow, sharing data and models among various disciplines, and integrating the overall process.

THE MODELING AND SIMULATION (M&S) PROCESS

Ship analyses and simulations are performed today in various disciplines. Such analysis models are almost always "hand-crafted" by skilled and experienced analysts. There is a need to improve upon the time, cost, and skill mix required to create such large-scale ship models

At a high level, but not necessarily in a prioritized order, M&S cost can be reduced by:

- Avoiding lengthy searches for (and collection of) requisite data and information,
- Minimizing touch labor time and re-work,
- Organizing data storage, retrieval, and process flow,
- Automating previously manual steps or operations,
- Reducing or eliminating steps to de-feature or simplify geometry,
- Improving mesh generation routines and algorithms,
- Expanding the use of Ship International Organization for Standardization (ISO) Standard for the Exchange of Product Model Data (STEP) Application Protocols (APs),
- Employing more CAE-centric processes (vice CAD-centric processes),
- Using Simulation-Specific Geometry (SSG) in place of detailed CAD geometry.

Given the high degree of collaboration in ship design today and the many parties involved, starting with a clean sheet of paper is not likely. On the other hand, all ship design organizations have a need to create analysis models for both older and existing designs for which digital data exchange may not be possible. Consequently, different approaches need to be considered.

Lengthy modeling times are not only encountered with full-ship analysis modeling efforts, but have been reported in other industries as well. Not long ago Sandia National Laboratories summarized their findings on the efforts involved in creating finite element analysis models (Reference 3).

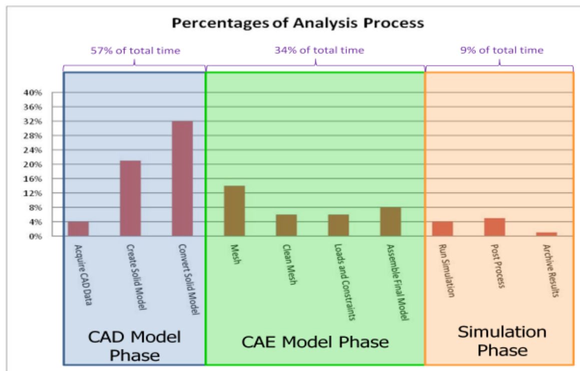

Figure 1 Percentages of Analysis Process

When this Sandia data is presented in bar chart form as shown in Figure 1(Reference 3), it tells a compelling story. First, we note that only 9% of the total effort is involved in making the analysis run or execution. Over 90% of the effort in their findings is in creation of the appropriate analysis model (CAD and CAE Modeling Phases). Furthermore, nearly 60% of the total effort is taken up before any analysis meshing is performed!

As the NSRP M&S project progressed, HII determined that there is a correlation to the analysis process for full ship analyses and smaller repetitive analyses that support the ship design. HII used this correlation to expand the research of reducing the analysis process to account for these smaller analyses.

Shipyard Analyses

In general, the number of analyses and calculations performed to support the design and construction of a ship is in the thousands range and vary in complexity from multiple hand calculations to highly advanced and coupled finite element analyses. And due to the iterative nature of ship design, these analyses and calculations are repeated multiple times. An example of theses analyses and calculations are:

- Full Ship Finite Element Analyses
- Full Ship Weight and Stability Calculations
- Structural Response Analyses and calculations
- Acoustic Analyses
- Signature Analyses
- Environmental Analyses
- Hull, Mechanical, and Electrical System Analyses

Figure 2 shows the typical areas of engineering that have analyses or calculations during the ship design process.

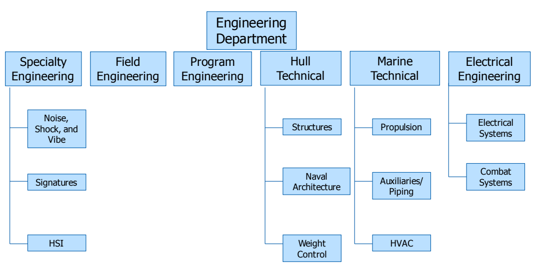

Figure 2 Typical Areas of Engineering

ISIGHT USAGE

For the NSRP M&S project, HII used Simulia's Isight program to aid in a number of analysis and calculation processes. A list of the processes integrated into Isight is provided below:

- Whipping Analysis
- Longitudinal Strength Analysis
- Post Processing/Data Reduction
- Analysis Post/Processing
- Linearized Stress Analysis
- Ship Weight Distribution
- Pipe Shock Test Specimen Design
- Pipe Hanger Support
- Bolt Stress Calculations
- RCS Analysis

Examples of some of the Isight Simflows are provided in Figures 3 through 5.

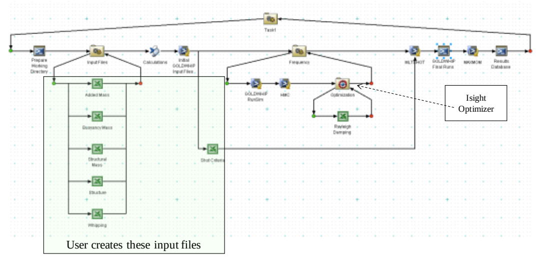

Figure 3 Whipping and Longitudinal Strength Simflow

Figure 3 is the Whipping and Longitudinal Strength Simflow. This process requires a significant amount of touch labor to perform this analysis and by integrating Isight into the process, HII was able to significantly reduce the required time to perform the analysis.

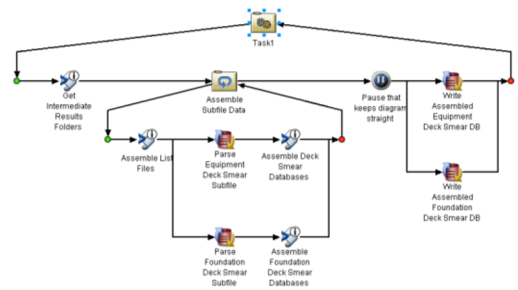

Figure 4 Full Ship Weight Distribution Simflow

Figure 4 is the Full Ship Weight Distribution Simflow. This simflow sorts and converts the ship weight database into a form that can be used for typical finite element analysis. This process typically requires a lot of user input and touch labor and by integrating Isight into the process, HII was able to significantly reduce the required time for this effort.

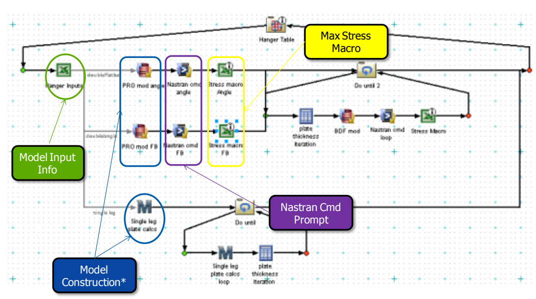

Figure 5 Pipe Hanger Support Simflow

Figure 5 is the Pipe Hanger Support Simflow. This simflow evaluates the required support structure for pipe hanger installation. This process does not reduce the cost to perform the process as many of the other processes do, but this Simflow directly reduces the required schedule to perform the process. Support structure is usually determined during construction of the ship and when pipe hangers are installed, the method requires a lot of personnel handling the information before the support structure is designed. This Simflow takes all of the relevant information from the structural engineers and places it into usable tables. Isight takes the as built parameters and calculates the stress on the structure. This stress is then compared to the data tables and the support structure is defined.

Benefits and Costs of Isight Usage

During the NSRP M&S project, HII created multiple Isight simflows for several distinct types of analyses, across several functional areas, and in multiple analysis domains. Ingalls Shipbuilding personnel successfully applied the Isight tool to this broad range of analysis problems. Figure 6 shows a comparison of the processes that were integrated into Isight and their overall cost reduction due to the integration.

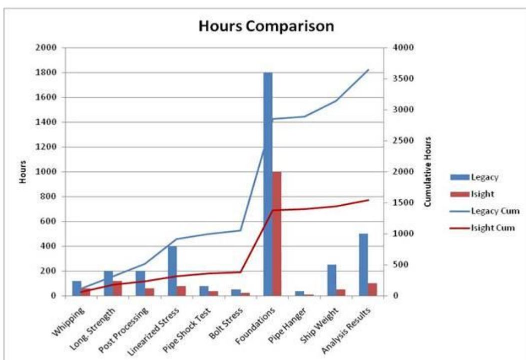

Figure 6 Hours Comparison

Process improvements from the use of Isight demonstrated that it is a 4 –fold Cost avoidance tool.

1. Schedule Reduction- One of the things that contributed to schedule reduction was Isight's extensive interoperability with other software applications. Figure 7 is an especially good example of many software applications being integrated into an Isight simflow.

Figure 7 Integrated Software Products

2. Reduction of Manual Errors- The Isight functionalities allows for semi-automation and reduction of manual errors. A good example of reduction of manual errors is shown in Figure 8.

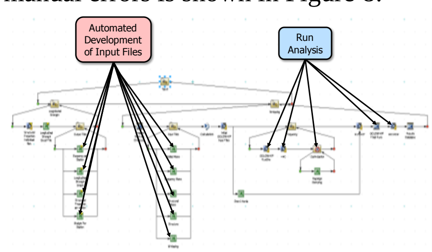

Figure 8 Reduction of Manual Errors

This simflow contains logic to automate the development of input files, thereby eliminating data transcription errors, and run the analysis using these input files. This semi-automated method of running the analysis significantly reduced the occurrence of manual data entry and execution errors.

3. Optimization Capability- The integration of Isight allows for a more in-depth comparison of design variations. Figures 9 and 10 show an example of handling design variations in a shipyard environment.

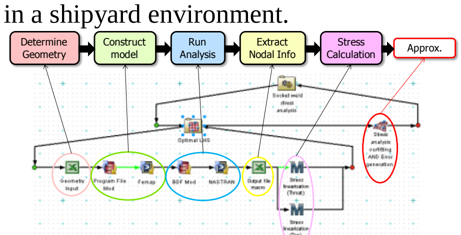

Figure 9 Simflow for Design Variations

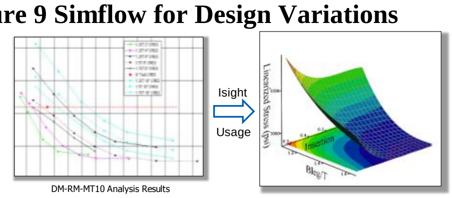

Figure 10 Results of Design Variations

Most design calculations are based on nominal dimensions. However, there are a number of material tolerances and manufacturing tolerances in shipbuilding. Isight allows for the evaluation of these tolerances with little additional cost or schedule.

4. Archived Documentation Capabilities- The existence of a simflow model in Isight improved the communication of the analysis set-up and results to other engineering personnel. In a demonstration of the adage, "A picture is worth a thousand words", the analysis was able to be communicated in a significantly improved way. The Isight simflow model also increased the configuration management of the analysis set-up, execution, and results. The digital input files, the simflow model, and the digital results could all be stored in one computer directory where the files could later be accessed to review the analysis results. Documented Isight simflows were used as a training tool for new analysts. Ingalls Shipbuilding personnel new to the functional areas were able to quickly grasp the analysis definition through the graphical layout of the process in Isight. There was a marked improvement in the time required by a new engineer to grasp the concept of the analysis, understand the results, and the engineering information represented in the results.

FOUNDATION ANALYSIS

One process that was a major factor in the evaluation of Isight in the shipyard design was foundation analysis. Foundation analysis is based on the ship specifications, which requires all foundations for Grade A and B equipment to be analyzed for shock. Analyses performed are static loading, modal, and Dynamic Design Analysis Method (DDAM) (Reference 4).

To support the ship design and construction, foundation analysis is schedule dependant. Foundation information comes from CAD model of the ship design. For example, the structure group may get 100 foundations to analyze at one time with an expected 2 week turnaround. Average analysis time is 24 hours (24 Hours per foundation for 100 foundations in two weeks would require 30 full time analysts.)

For the purposes of determining the best way to optimize and automate the process, foundation analysis was broken into 3 parts:

- Part 1- CAD Model to FEA Model
- Part 2- Finite Element Analysis and Evaluation
- Part 3- Optimization

A proof of concept for Part 1 was developed by Dassault Sytemes Simulia Corporation using the CATIA software as its main engine. Figure 11 provides the basic concept of how the tool works.

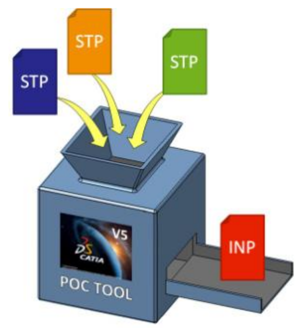

Figure 11 Foundation Part 1 Proof of Concept

HII developed the simflow for part 2 of the foundation analysis. Figure 12 shows the flow chart of the foundation analysis. All but the result evaluation have been incorporated into one Isight Simflow.

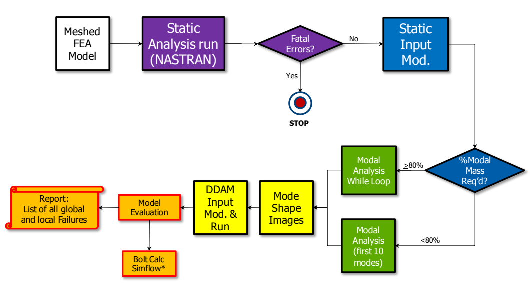

Figure 12 Flow Chart for Foundation Analysis

Figure 13 is Isight simflow for the foundation analysis. The required input for the simflow is a meshed FEA model of the foundation.

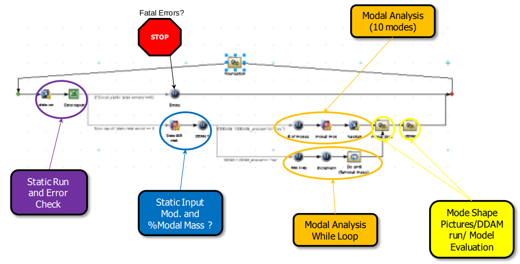

Figure 13 Simflow for Foundation Analysis

The simflow performs the check on the FEA model and completes the static loading, modal, and DDAM portion of the process.

The simflow, at this point, only provides the analysis results, and does not evaluate them. This is based on the complexity of the stress criteria. Because of the complexity of the stress criteria, HII determined the most logical way to evaluate the foundation analysis results is to use a new simflow similar to the simflow in Figure 14.

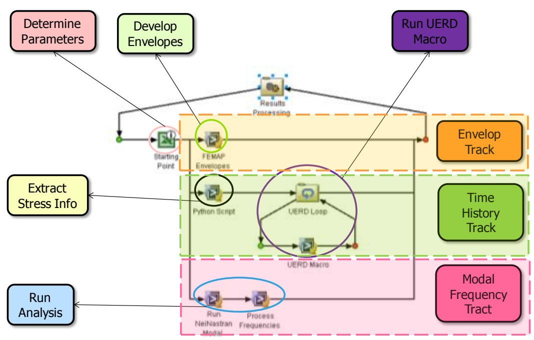

Figure 14 Post-Process Analysis Results Simflow

The new simflow would allow the results to be filtered. With the development of macros and python scripts the filters would be able to evaluate each stress separately and provide a package to the user that is optimal for evaluating the foundation design.

Part 3 of the foundation analysis is optimization. Optimization based on results from foundation simflow. Optimization will be semi- automated and be based on the DDAM stress criteria. It will be considered semi-automated because it will still require some evaluation from analyst.

The optimization approach for foundations has to be developed in a manner that it will be efficient for the ship design. A full optimization method, where the process does not account for standard structural member sizes or piece parts, may reduce the stress in the foundation but may increase the cost of the constructing the foundation. Also, the foundation analysis is performed during the ship design iterative process. Any optimization effort would have to ensure that design rework does not significantly increase. With those factors in mind, optimizing the foundation analysis to reduce stress, weight, piece parts or welding would be an improvement to the existing process.

The optimized foundation analysis Isight simflow is shown in Figure 15.

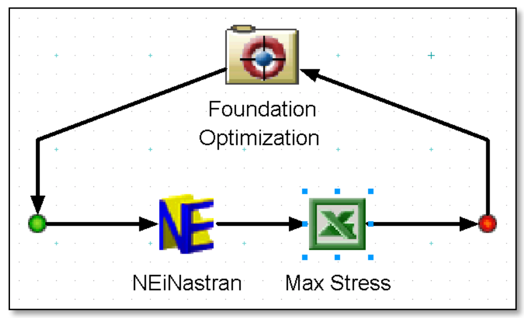

Figure 15 Foundation Optimization Simflow

Foundation Analysis Results

In the evaluation of the foundation analysis part 2 simflow, HII determined that the integration of Isight into the process helped the structural group meet their schedule to support the ship design. As shown in figure 16, Isight was able to reduce the time required to analyze the foundation from 10 hours to 2 hours. This is an 80% reduction.

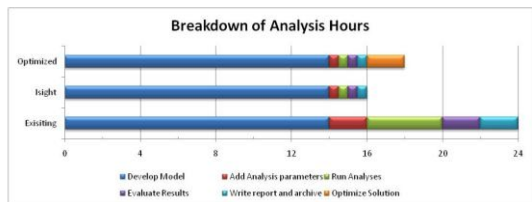

Figure 16 Breakdown of Analysis Hours

From the original scenario, where the structure group had to analyze 100 foundations in 2 weeks, Isight reduced the number of full time analysts from 30 to 20 and allowed the analyses to be completed without any overtime. Figure 17 describes the scenario in a bar chart form.

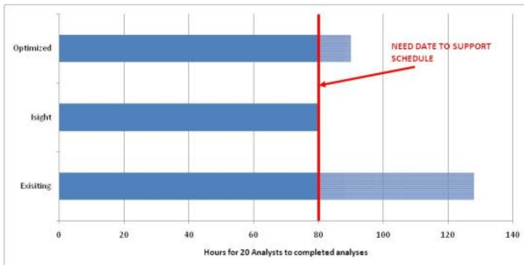

Figure 17 Schedule Comparison of Analysis Hours

Using the optimization simflow for the foundations, the amount of time did increase (2 hours per foundation. But in the 100 foundation scenario, that increase resulted in 10 extra hours to provide Design with an optimized solution for each foundation. The optimized solution decreased the total weight of all the foundations by 34.6% from the initial condition used.

CONCLUSION

As Navy shipbuilding budgets continue to focus on reducing cost, there is ever increasing pressure on shipbuilders to reduce ship acquisition costs and improve timeliness.

Through the project NSRP M&S, HII has evaluated and demonstrated the integration of the Isight software into the shipyard's ship design and analysis processes can help the reduce costs in both the ship design and construction phases.

In particular, HII determined that Isight is a 4-fold cost avoidance tool:

1. Schedule Reduction
2. Reduction of Manual Errors
3. Optimization Capability
4. Archived Documentation

In addition to the 10 simflows that were developed, HII also incorporated the foundation analysis into Isight and demonstrated that the use of Isight helps the structure group support the ship design and construction process.

ACKNOWLEDGEMENTS

The authors would like to thank all the members of the M&S team who contributed to the success of the project, including:

James Weathers — Ingalls Shipbuilding
Jarrod Gilmore — Ingalls Shipbuilding

Stewart Moore — Electric Boat Corporation
Stephen Gordon — Electric Boat Corporation
Nicholas Barner — Electric Boat Corporation

John Modesto — Dassault Systemes Simulia Corporation
Justin Vianese — Dassault Systemes Simulia Corporation
David Haberman — Dassault Systemes Simulia Corporation
Dave Naehring — Dassault Systemes Simulia Corporation

The subject work was sponsored by NSRP ASE under Subcontract Agreement 2007-381.

REFERENCES

1. Moore, S., and S. Gordon, "M&S-1 Project Report, Improved Methods for Generation of Full-Ship Simulation/Analysis Models", Electric Boat Report, June 30, 2008 (Performed under NSRP Technology Investment Agreement TIA 2007-381).

2. Moore, S., and S. Gordon, "M&S-2 Project Report, Improved Methods for Generation of Full-Ship Simulation/Analysis Models", Electric Boat Report, June 30, 2009 (Performed under NSRP Technology Investment Agreement TIA 2008-381).

3. Blacker, Ted, "Moving Computational Analysis into Design & Engineering", Sandia National Laboratories Presentation, DARPA Workshop - Automation of Analysis Model Creation, October 25-26, 2005.

4. "Shock Design Criteria for Surface Ships", NAVSEA 0908-LP-000-3010 Rev. 1, September 1995.