## Title

**Improved Methods for the Generation of Full-Ship Simulation/Analysis Models**
**NSRP ASE Subcontract Agreement 2007-381**

## Executive overview

Large full-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. In order to perform a full ship computational analysis, the engineering analyst must have or create an analysis-ready model. Following current work practices, a computer-aided design (CAD) database of the vessel is created, primarily for design disclosure and manufacturing rather than for analysis. Consequently, the model may not suitable or easily modified to create an analysis-ready model. Several thousand man hours are required to obtain data and prepare a model that is usable for analyses. Furthermore, solely expanding use of modeling and simulation tools, without accompanying changes in the model generation approach, will not deliver significant savings. Model generation is a complex effort and often is the major cost of full ship analysis.

The objective of this project (M&S-1) is to define, demonstrate, and provide examples of approaches to reduce the time and cost of creating computational analysis models for shock (and other) simulations. In particular, the focus is on very large models often representing full-scale ships and Naval vessels. A primary motivation for this work is 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.

Teammates for this project are: Electric Boat Corporation, Northrop Grumman Ship Building (NGSB), TechnoSoft Inc., Engineous Software, Inc., and Product Data Services Corp. (PDSC).

## Description of methodology

This project's objective was to investigate technologies for reducing the cycle time required to develop large-scale, full-ship analysis models for strength, stress, shock, and acoustic simulation and assessment. It responds to Navy Program Executive Officer (PEO) interest in expanding the use of modeling and simulation to reduce costs associated with current methods of ship structural testing and analysis. In part, the team has built upon past success in satisfying live-fire legislation through a combination of modeling, analysis and experimental testing; as well as considerable other prior NSRP work in design data interoperability and standards, and prior industry investments in ship design tools.

The M&S-1 project is part of a concerted effort to address methods for more rapidly generating large scale, full-ship analysis models for strength, stress, shock, and acoustic simulation and assessment. As is well known, current CAD-CAE tools and industry approaches are more than adequate on smaller scales, and can even be "seamless" in certain limited situations. However, at full-ship scale they are not practical, particularly as the design progresses into the detailed design stage and prevailing CAD product model definition takes on a "manufacturing definition" flavor, i.e. several hundred thousand structural solid model representations, generally for each manufactured piece of steel or plate. At this scale, the task of identifying and extracting all the appropriate data can be horrendous. Furthermore, too much assembling, de-featuring, and editing is required to obtain an idealization suitable for full ship simulation.

Ultimately, the envisioned environment will facilitate affordable ship development by integrating a feature-based modeling environment with low and high fidelity analysis and simulation tools for the conceptual, preliminary and detailed design and synthesis of ships. The system will significantly enhance the overall engineering process of evaluating potential ship concepts. Integrating the design process and the multidisciplinary analyses to support and link different engineering stages from basic concepts to detailed processes will facilitate concurrent engineering, reducing cost and design cycle time. It introduces analysis at the earliest stages of the design process. The coupling between design and analyses facilitates design exploration and provides guidance for designers interacting across disciplinary barriers to rapidly assess viability of a design concept.

## Implementation and Technology Transfer

This project was conceived and defined at the outset to accommodate the analysis modeling needs of both surface ships and submarines. Accordingly we planned for parallel tracks or "threads". In this way it is believed that common tools and approaches, or a middle "ground", could be accommodated as well as unique needs, tools, or methods which may pertain only to either submarines or surface ships. Different CAD and CAE software codes are employed at the various industrial and Navy organizations involved in full-ship modeling and simulation activities. Consequently, one goal of these efforts is to define, implement, and demonstration the utility of open architecture frameworks.

During the project the two tracks illustrated somewhat different framework approaches. The surface ship track (led by NGSB) illustrated the insertion of, and use of, a new tool, the AMWaves code, in place of other existing tools and a considerable number of separate manual steps. In the submarine track, EB focused on using the iSIGHT-FD system to integrate a number of legacy CAE concept tools into a more efficient process. Both shipyards also employed iSIGHT-FD to automate a series of analyses to evaluate the most severe charge locations for ship whipping analyses.

Major portions of the demonstrated technology can ultimately be transferable as commercially available product offerings created specifically for shipbuilding business requirements. In particular, the M&S project team foresees the following:

- M&S protocols, workflows and process improvements will become industry and/or international standards.
- STEP translators developed will be deployed by vendors that service the U.S. shipbuilding industry.
- Software developed by commercial software partners can/will be made commercially available.

In addition, in late May, 2008, members of the project team attended the first in a series of ONR/NAVSEA/CREATE sponsored Ship Design Process Workshops. The primary goal of attending these workshops was to support the development of a Navy Ship Design Tool Roadmap and to ensure these independent efforts are coordinated and synergistic.

**Resources needed for Implementation**

In the M&S-1 project, two organizations supplied framework tools and capabilities. These are Engineous's iSIGHT-FD product, and the AMWaves software from TechnoSoft. Installation of each tool set was completed at both NGSS and EB sites.

In addition, training was provided at each of the vendor's sites. The iSIGHT-FD training was provided at Engineous's facilities in Cary, NC on October 23-24, 2007. AMWaves and AML training were provided by TechnoSoft in Cincinnati, OH November 28-30, 2007. Various team members participated in these training sessions.

During early phases of the M&S-1 project, personnel at NGSS and EB learned about these products, worked with specific implementations to prepare demonstrations (discussed later), and in some cases defined needed improvements and further enhancements.

Members of the M&S-1 team spent four days at NAVSEA Carderock in Bethesda, MD in order to attend Advanced Ship & Submarine Evaluation Tool (ASSET) Version 6 and Leading Edge Architecture for Prototyping Systems (LEAPS) Version 4 software training. Both tools are developed and maintained by Carderock's Design Tools Development Branch, Code 223 and are utilized by NAVSEA for modeling and simulation purposes.

**Evaluation and analysis methods**

The M&S-1 team as developed and demonstrated two modeling and simulation environments that supports ship design and analysis automation from the early concept to the detailed stages. For both the demonstrated surface ship and submarine tracks we have implemented unique approaches that focus on supporting multilevel modeling fidelity within a single design environment. The demonstrated environments support workflow process automation for design and analysis of surface ships and submarines at the various stages of the process (conceptual, preliminary, and detailed). Initial investigations have shown a reduction in concept-to-analysis cycle time and allow greater investigation of the entire design space. The more robust design space investigations can result in improved

cost/benefit analyses, the support of live-fire test by analysis and reduce total ship acquisition costs.

In particular, the M&S-1 team has:

- Showcased several newer capabilities which are applicable to both surface ships and submarines.
- Integrated legacy tools into more efficient M&S process flows.
- Automated several key steps in the modeling process.
- Illustrated more automated mesh generation, which can be merged with analysis and post-processing
- Highlighted areas in which cost saving can be achieved and demonstrated.

A project demonstration was held  was held April 2, 2008 at the General Dynamics / Electric Boat - Washington Engineering Office (WEO), Maritime Plaza Suite 100, 1201 M. Street SE, Washington, D.C. 20003. This demonstration was presented in conjunction with the NSRP ISE-6 Project demonstration.

The demonstrations gave an overview of the background to the M&S-1 project and some of the differences and aspects involved in analytical model generation. During the project demonstrations the two tracks illustrated somewhat different framework approaches. The surface ship track (led by NGSB) illustrated the insertion of, and use of, a new tool, the AMWaves software developed by TechnoSoft, Inc., in place of other existing tools and a considerable number of separate manual steps. In the submarine track demo, EBC focused on using the Engineous' iSIGHT-FD softare system to integrate a number of legacy CAE concept tools into a more efficient process. Both shipyards also employed iSIGHT-FD to automate a series of analyses to evaluate the most severe charge locations for ship whipping analyses.

General Dynamics/Electric Boat Corporation, Northrop Grumman Ship Building, and their team members have proposed and been awarded a project for ***Improved Methods for Generation of Full-Ship Simulation/Analysis Models 2*** (M&S-2***)***. The proposed project is a continuation of the M&S-1 NSRP project.

In the M&S-2 project, parallel task threads will continue to address application to both Naval surface ships and submarines.  The use of open architectures will continue to be fostered, and employment of shipbuilding (and other) ISO STEP standards will be investigated and employed wherever appropriate. New or updated automated full-ship meshing approaches will be assessed and prototyped. Improved simulation data handling and work flow methodology will be explored for dealing with these very large ship simulation models and their analysis results that must be maintained by shipyards. The

## Cost Benefit analysis/ROI

During this M&S-1 project, team members prototyped and demonstrated improvements to shipyard shock and vibration analysis process by using the both new software technology and the integration of existing software tool. A combination of these tools and improved integration led to a reduction in the time required for the creation of the

simulation specific geometry when building the analysis model, property assignment to structural objects in the model, and the ability to use one model for many analysesand demonstrates a predicted ability to measure shock and vibration analysis efforts in terms of man-days and man-weeks instead of man-months.

In addition, the process and tool improvements provided an added capability that the shipyards did not have before; the ability to iterate on multiple new designs. Previously the extend time required to create one analysis model, meant that the analyst only had time to play "what if" on that one model. He was limited to varying the applied loads and structural material of the ship to observe changes in behavior. This resulted in a limited exploration of the design space. However, with the order of magnitude reduction in model creation and analysis time afforded by implemented framework, the analyst is able explore many more alternative designs. The analyst can vary the structural configuration, in addition to the applied loads and materials. Essentially the analyst can more rapidly create new designs and analyze their behaviors in a much shorter time span, thereby enabling a richer exploration of the design space.

## Lessons Learned

As Navy shipbuilding budgets continue to focus on reducing cost, there is ever increasing pressure on shipbuilders to reduce ship acquisition costs and timeliness. One specific cost driver is the desire to optimize the use of modeling and simulation to reduce the cost of actual shock testing of military assets such as full ships. The cost of live-fire, full-ship shock tests has become prohibitive. Additionally, Navy analysis and approval processes require full-ship analysis and simulation models. Clearly, efficient use of modeling and simulation tools and approaches, and continuing improvements or creation of new tools, remains a Navy and industry goal. In summary, there is significant need to:

- Reduce Engineering Labor (US Navy spends $5B-$7B per year in all aspects of ship design and engineering).
- Reduce Reliance on full scale, low intensity, ship shock trials, which continue to be expensive, risky, and time consuming. Environmental approvals are increasingly difficult to obtain.
- Optimize ship designs to improve cost, performance, reliability, and safety.

In summary we believe that:

1. Creating full-ship FEA analysis models need not take months (or even a year) of calendar time.
2. Months of effort can be reduced to weeks and days, even hours.
3. Waiting for the existence of detailed CAD geometry is not necessary, can be counter-productive, and may be wrong.
4. As we have shown, one should focus more on employing CAE-centric tools and approaches for modeling and analysis.
5. M&S frameworks and simulation management are important.
6. ISO STEP standards can be effectively employed for data exchange (but some improvements are needed!)

7. Following “Lean” principals, we should advocate greater use of “Simulation-Specific” Geometry (SSG) and employ parametric geometry representations.