NSRP RA Project 2017-443
“Ship Structural Design Optimization for Improved Producibility and Enhanced Life-Cycle Performance”

June 20, 2017
Program rationale

Design engineering and production engineering includes elements that are important enablers of higher levels of productivity ...
One of the barriers to changing the design is the design cost, so there would be benefit in reviewing the approach to the naval design process with a view to minimizing cost.”

“2014 US Naval Shipbuilding and Repair Industry Benchmarking” study by ASN (RDA)

This project directly addresses this shortcoming by enabling an existing design tool, MAESTRO, to:

• **Improve quality of ship construction**
• **Reduce ship structural production costs**
• **Reduce Total Ownership Costs**
The program team

- **Fincantieri Marinette Marine**
  - Project Lead, shipyard implementation
- **DRS Technologies, Advanced Marine Technology Center**
  - Naval architects & software developers, creators of MAESTRO
- **NSWC-CD Code 65**
  - US Navy lead organization for ship structural design
- **Ship Design USA (Bob Keane)**
  - Former US Navy Chief Naval Architect, advisor on Navy ship design & construction
- **SPAR Associates**
  - SMEs in ship cost-estimating and production planning
- **P. Jaquith & Associates (Pete Jaquith)**
  - SME in Lean Design and Design for Production
Objective

Develop a ship structural design and optimization modeling and simulation capability that shipbuilders will be able to utilize to enable ship structures to be holistically designed to:

- meet structural performance and safety criteria
- facilitate optimization for producibility
- simultaneously reduce production costs, enhance structural life-cycle and in-service performance, and generate total ownership cost reductions.
Program Design Cycle/Schedule

4 - six month phases, April 2017-March 2019

1. Identify Improvements
2. Develop Improvements
3. Testing and Demo
The underlying technology: MAESTRO

The only FEA tool in the world specifically created for the *analysis, design and optimization* of ship structures

- Rapid Structural Modeling
- Ship-based Loading
- Finite Element Analysis
- Structural Evaluation
- Detailed Stress Analysis
- Vibration Analysis
- Extreme Load Analysis
- Fatigue Analysis
- Optimization
Full ship modeling
Ship-based loading

- Lightship mass distribution
- Hydrostatic Loads
- Hydrodynamic Loads
- Tank Loads
- Cargo Masses
- Accelerations (6 d.o.f.)
- Pressure Loads
- Boundary Conditions
Finite element analysis

Model of International Frigate courtesy of NAPA
Structural evaluation

Evaluation includes limit states from Hughes, ULSAP, NVR, HSNC, CSR
MAESTRO optimizes the ship’s structure against all load cases and all limit states for safety, weight, VCG and cost.
Optimization for a system of stiffened panels

1. Optimization model preparation (define panels and clusters)
2. Finite Element Analysis (full ship)
3. Update loads for each panel (including directional stresses)
4. Failure mode evaluation to find the critical panel of each cluster
   - Stop
   - Criteria
5. Local optimize: Each critical panel (Weight & Safety) (MOGA/PSA/PSO/Exhaustive/...)
   - Panel A
   - Panel B
   - ...
6. Global Optimization
   - Use the Pareto front of each panel, optimize hull girder cross section moment of inertia/VCG/Cost, etc. (Multi-objective Heuristic Optimization)
7. Update Structure Scantlings
A “design cluster” is a group of panels or grillages for which it is desired to have uniform design variables (e.g. same plate thickness).

Design clusters MUST be defined by the shipyard production team.
Stiffened Panel and Fabricated Beam Metrics for Optimization

• Plate thickness & beam scantlings (or plate/beam library)
• Panel line compatibility (automation) factors
  • Width of panel line can drive/limit design cluster parameters
• Plate-stiffener combination constraints, e.g. thickness of stiffener web to thickness of plate
• Ratio constraints, e.g., flange breadth vs. web height
• Material costs, e.g. $$/kg or $$/length
• Fabrication costs, e.g. $$/welded length
• Handling costs, e.g. factor for thicker plate
Phase 1 Improvements

- **Current code**: In coordination with shipyard production teams, improve the inputs for MAESTRO’s Optimization Parameters, Constraints, and Objective Functions.

- **New capability**: Design and prototype a new concept design level MAESTRO module to support automated structural optimization during Concept Design phase.

**Demo Capability at SNAME in October**
Questions?