Extended Modularization of Ship Design & Build Strategy

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World-class shipyards have been exploiting build strategies that have enabled them to dramatically lower their costs, improve construction quality and extend ship design features and capabilities.

These strategies fall into the following general categories:

1. Improved manufacturing & assembly methods
2. Improved procurement & material control
3. Improved business processes
4. Improved ship designs & engineering

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Improved Manufacturing & Assembly Methods:

- Pre-outfitted hull block construction
- Outfitted equipment & systems modules
- Group technology manufacturing methods
- Improved assembly technologies
- Cross-trade work agreements
- Outsourcing specialty work
- Reduced non-value added labor costs
- Minimized/elimination of expensive staging
- Minimized worker walking time
- Increased under-cover assembly operations

Improved Procurement & Material Control

- Near-in-time procurement scheduling
- Improved vendor relations & pricing agreements
- Material work order kitting
- Standardized material parts & components
- Material buffer storage nearer to worksites

Improved Business Processes

- Streamlined & integrated departmental business process management
- Improved labor/material/subcontractor planning & scheduling
- Timely & accurate progress, cost & earned value reporting
- Improved cost estimating & faster RFP responses
- Improved progress & cost management metrics
- Automated data collection systems
- Contract payments supporting advanced building methods & efficiencies
- Streamlined government contract oversight requirements
- Streamlined contract change management

Improved Ship Designs & Engineering

- Integrated design & engineering systems
- Standardized (repeatable) components & interim products
- Simplified ship & ship systems designs

The efficient shipyard pursues strategies that maximize productivity of the assembly processes:

- o Maximize under-cover work
- o Maximize down-hand work
- o Maximize assurance that correct material is available on time to support production
- o Minimize material handling and storage requirements
- o Eliminate all instances of non-value labor costs
- o Maximize access to work for not only the worker, but also the supply of material for the worker
- o Minimize number and complexity of parts
- o Maximize opportunities for repeatable standardized parts and assemblies
- o Maximize responsibility and problem solving down to the worker level

Modules can be developed in a wide variety of ways:

- Outfit and equipment modules,
- Hull assembly blocks,
  Outfitted hull blocks, and
- Outfitted panel assemblies

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Typical Hull Modular Blocks

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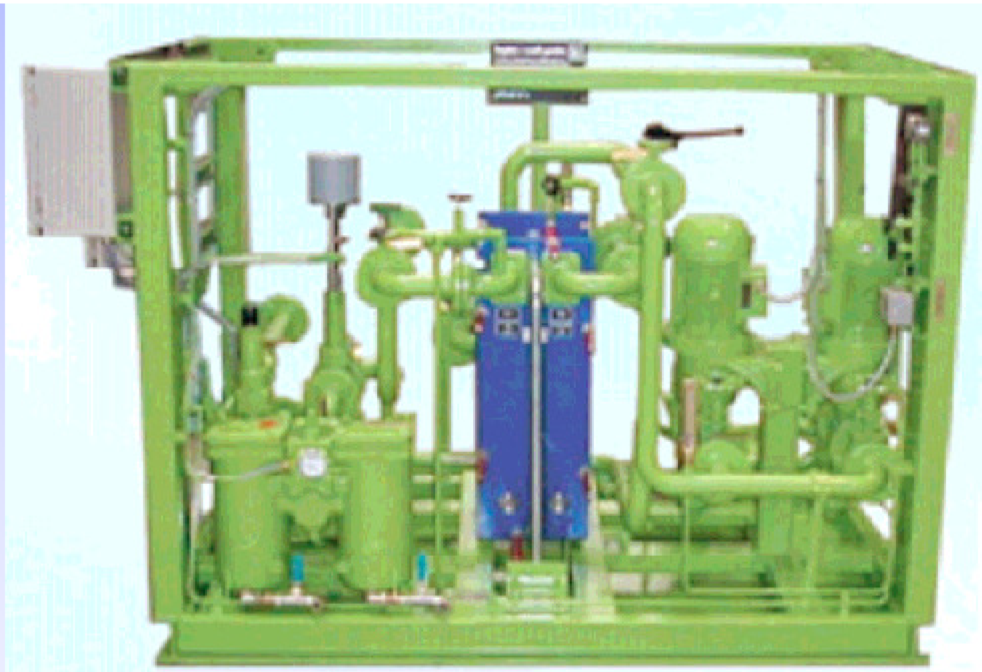
Expanded use of modules carry the concept of early stage construction cost savings even further.

On unit outfit may be as small as a single piece of equipment mounted on its foundation and ready to install on panel, on block or on board.

Or, on unit outfit can be a complex assembly of equipment, piping, electrical and other systems all pre-mounted on a support structure.



Turbocharger Lube Oil Module

Accommodation Module

Alfa Laval Module

Lube Oil w/Pumps Module

Westfalia Separator Module

Hydrophore Module

Sewage Treatment Module

Refrigeration Compressor Module

Expanded application of ship modules have been successfully developed by various European shipbuilders (for example, Thyssen Nordseewerke, Schelde Naval Shipbuilding, Blohm & Voss Gmbh, Abeking & Rasmussen).

New Construction Benefits

- Shorten ship construction time with modules built in parallel.
- Shortened time saves cost with lower overhead, less impact of inflation
- Mass production of modules saves cost from learning effects. Additional efficiencies gained if modules are standardized and applicable to multiple ship types and classes.
- Modules can be built by a competitive industry that does not rely on the fully integrated shipyard that is less productive… more opportunities for smaller business. This can lead to greater participation of supplier base that can assume more development responsibilities to improve quality and reduce costs further.
- Lead ship costs should be lower because modular approach is less inter-dependent of other systems subject to change orders.
- Lower cost means more product can be built for available funds.
- Eventually, standardized modules can lead to lower costs for non-recurring design and engineering.

Ship Maintenance Benefits

- Modules can be easily removed from onboard and repaired in shop
- Less costly to upgrade, repair or replace (on-shore work less costly than on-board)
- Faster turn-around time to repair/replace modules
- Even faster turn-around with Swap-out/Swap-in scenario of selected modules
- Increase fleet operation time
- Decrease time in shipyard

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Ship Operations Benefits

- Modules provide more flexibility for a standard ship platform
- Modules allow more focus of purpose for specific operating requirements
- Modules may minimize need for incorporating unnecessary systems.

Other industries have long exploited the benefits of modular construction:

- Aircraft – F4 began modularization; F35 extensive use of modules
- Cars – parts and components, often interchangeable between different models
- Home appliances – parts and components

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There are precautions that must be taken in order to minimize failures in applying modular construction techniques:

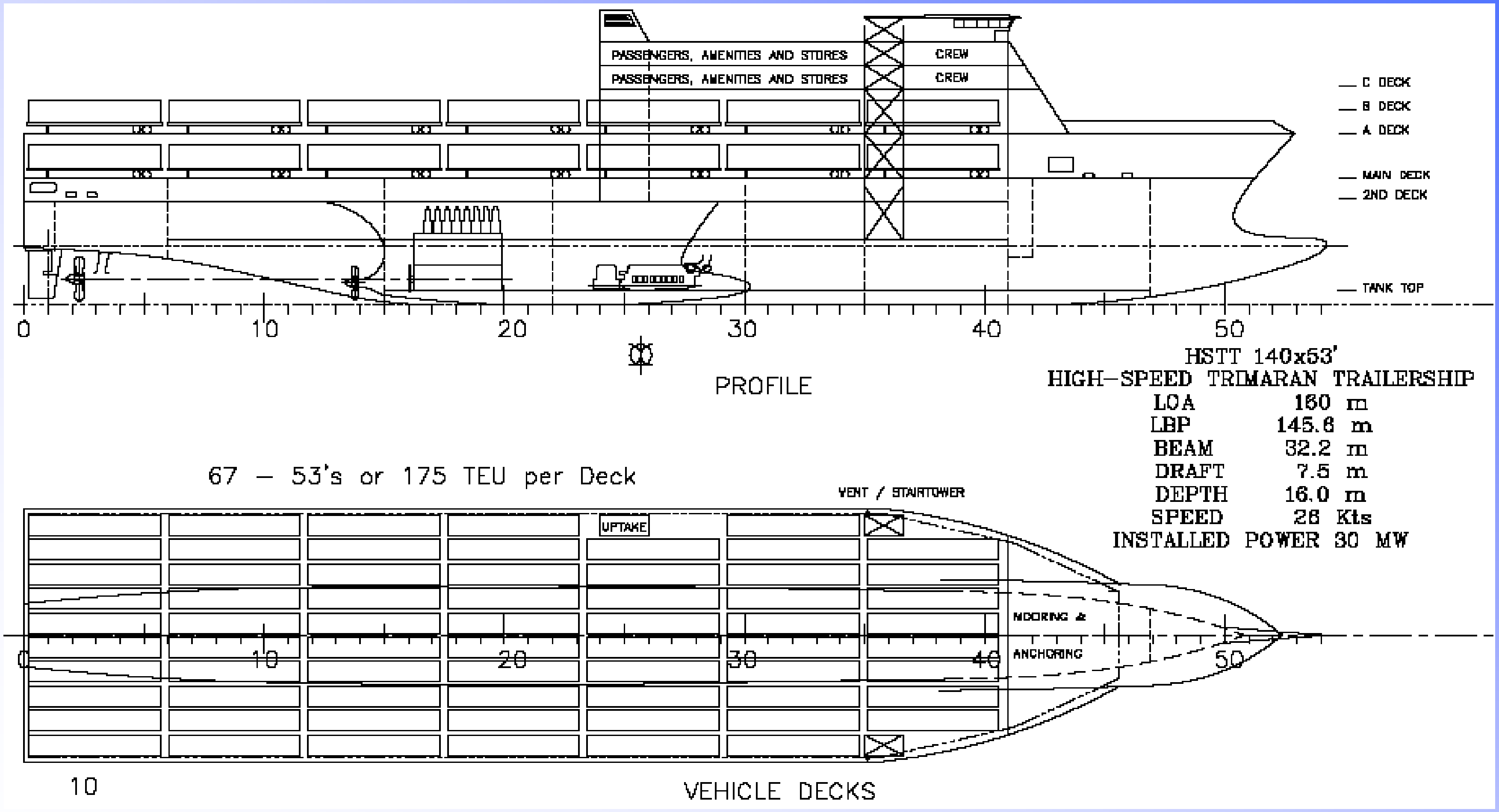
• Requires better than normal engineering
• Requires better than normal quality assurance
• Requires higher level of design standards to minimize interferences and disconnects.

To illustrate the cost savings potential of modularized design and build strategies comparable cost estimates were produced:

1. A cost estimate for a conventional design and build strategy. Conventional means using modern hull block construction methods, but without use of advanced modularized systems and equipment.
2. A cost estimate for a modularized design and build strategy. This approach expands upon efficiencies of current conventional methods.

The cost estimates were produced for a notional HST140-53’ Trailership

The CCDoTT HST140-53' Trailership



SPAR Cost Model

The cost analysis for the HST140-53' Trailership was done using SPAR's trimaran cost model. The cost model estimates concept and preliminary ship designs.

The cost model permits quick assessments of costs, risk, and design/mission trade-off alternatives.

The model provides a range of structural, powering, equipment and ship system selections to predict weights, costs and various performance characteristics.

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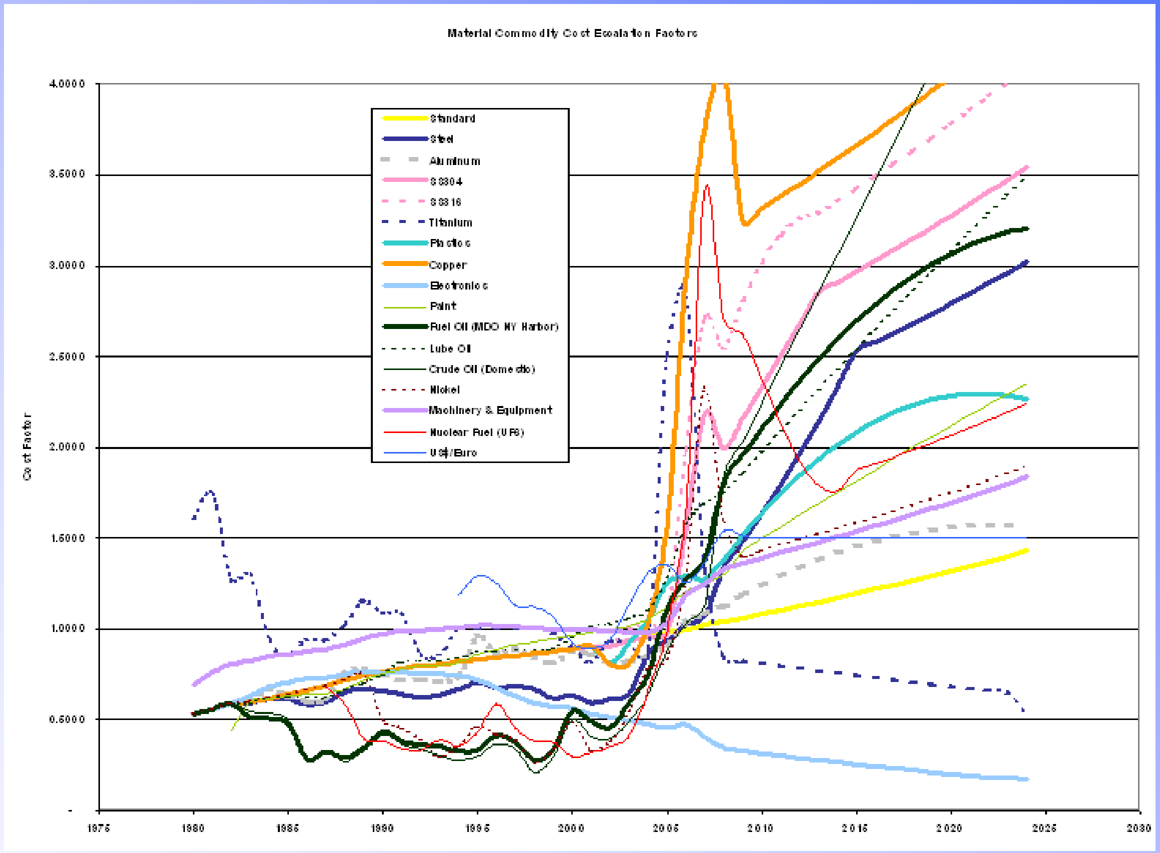
Material & equipment prices are escalated/de-escalated by type commodity. Escalation factors (graphic below), both historical and predicted, are obtained from U.S. Government and industry-recognized commercial and foreign sources.



All labor estimates and material costing is provided by the cost model from internal manufacturing and material cost estimating relationships (CERs).

These CERs are based upon a notional (generic) modern mid-size U.S. commercial shipbuilding facility. Various productivity factors are used to model specific types of shipbuilders.

The cost model operates using CERs based on a wide range of cost metrics including weight for structural components, kW for powering and electric generation, ship volumes, deck areas, physical hull dimensions, crew size and type breakdowns, etc.

The cost model generates cost estimates at approximately SWBS level 3 detail and summarizes them as follows:

Non-Recurring Costs

Basic Research - Concept Design
Preliminary Design
Functional Design
Production Engineering & Construction Drawings
Production Planning & Scheduling
Purchase Specs & Support
ILS, Spares & Load Items
Contract Engineering Management
Contingency Labor:
Contract Detail Design Package (Optional)
Miscellaneous Material & Support
Jigs, Cradles, & Templates, Tools & Instruments

Recurring Costs

SWBS	
100	Structures
200	Propulsion
300	Electrical
400	Electronics & Navigation
500	Auxiliary Systems
600	Outfit & Furnishings
700	Armament
800	Technical Support
900	Shipyard Services
1000	Margin, Bonds & Insurance

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The cost model also produces estimated average costs for <u>multiple ship construction</u> programs developed with expected learning factors.

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Cost Risk:
The models develop cost risk within several focus areas

- Cost risk of applied CERs
- Shipbuilder's experience risk
- Engineering performance risk
- Cost risk due to compressed production schedule
- Cost risk of rework due to immature detail engineering when overlapping with production

Baseline HSTT Build Strategy Scenarios

1. Mid-size U.S. commercial shipbuilder using more traditional (conventional), but modern shipbuilding methods, including pre-fitted hull block construction.

2. Mid-size U.S. commercial shipbuilder using pre-fitted hull block construction, but also extensive application of equipment and system modules.

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Modular construction promotes cost and schedule benefits from early stage construction.

There are a number of rules of thumb that have been applied to estimate the savings. Labor costs on board can be 3-5 times and higher than equivalent work done in the shop or on the platen.

Since modules can be relatively small, they can be manufactured and assembled by smaller, more competitive manufacturers.

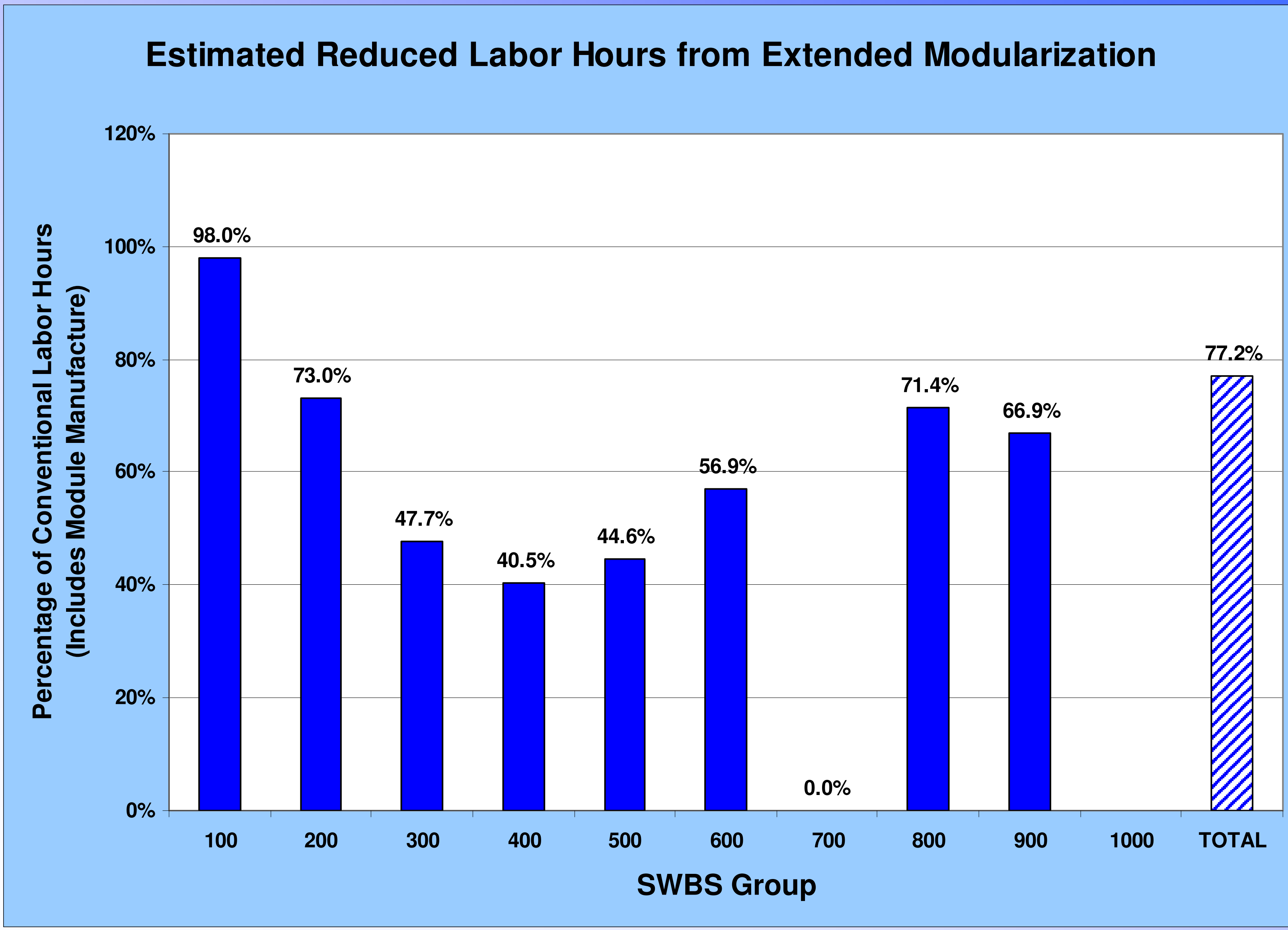
Such alternative manufacturers can be significantly more efficient than the traditional fully-integrated shipyard that often struggles to maintain high levels of efficiency for the many different worker trades and facilities needed to build a ship.

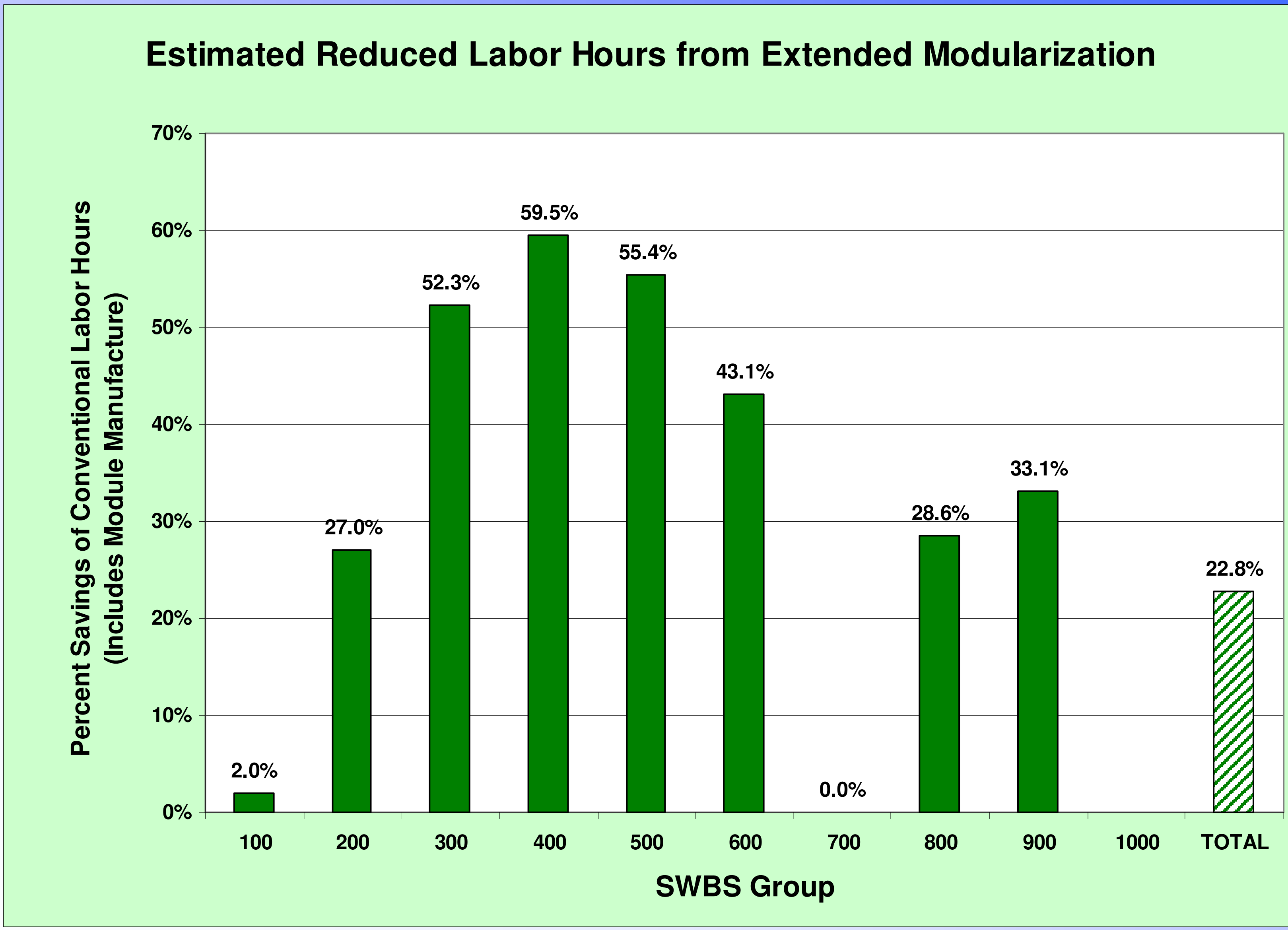
As modules become more and more standardized, still more cost and schedule benefits can be garnered as efficiency increases from repetitive manufacturing.

Use of standard modules also can reduce the cost and schedule of non-recurring ship design and engineering.

Work Type	% Total Modularized	Onboard Factor	On Block Factor	On Unit Factor
Piping - OMS	85.00%	1.000	0.530	0.280
HVAC - Rectangual Duct	85.00%	1.000	0.800	0.400
HVAC - Spiral Duct	85.00%	1.000	0.650	0.325
HVAC - Fans	85.00%	1.000	0.650	0.325
HVAC - Air Handlers	85.00%	1.000	0.800	0.400
HVAC - Spools	85.00%	1.000	0.650	0.325
HVAC - Fire Dampers	85.00%	1.000	0.750	0.375
Electric Cable (Local)	85.00%	1.000	0.500	0.200
Auxiliaries - IMS	85.00%	1.000	0.650	0.325
Piping - IMS	85.00%	1.000	0.800	0.400
Cable Trays - IMS	85.00%	1.000	0.800	0.400
Staging - IMS	85.00%	1.000	0.800	0.400
Exhaust Casing - IMS	95.00%	1.000	0.500	0.500
Casing Vent Trunk	95.00%	1.000	0.500	0.500
Foundations	100.00%	1.000	0.830	0.390
Seats - IMS	100.00%	1.000	0.750	0.375
Paint - Excluding Block Paint	85.00%	1.000	0.690	0.170
Paint - Block Paint	40.00%	1.000	0.800	
Paint - Unit Paint	20.00%	1.000		0.500
Propulsion Machinery	90.0%	1.000	0.700	
Outfit Machinery	90.0%	1.000	0.500	0.250
Electronics	85.00%	1.000		0.300
Outfit Equipment	85.00%			0.300
Armament	85.00%			0.300
Structures	85.00%	variable	variable	
Cable, Machinery Spaces	80.00%		0.50	
Cable, Accommodations Spaces	80.00%		0.50	
Cable, Superstructure	80.00%		0.50	
Cable, Exterior Decks	50.00%		0.85	

% Total Modularization = Estimated Maximum Percentage of Work that can be Modularized beyond conventional methods.
Onboard Factor = Maximum Labor Cost at Onboard Stage of Construction
On Block Factor = Percentage Labor Cost for On-Block Work Relative to Onboard Cost
On Unit Factor = Percentage Labor Cost for On-Unit Work Relative to Onboard Cost


Estimated Reduced Labor Hours from Extended Modularization
Percentage of Conventional Labor Hours
(Includes Module Manufacture)
120%
100%
80%
60%
40%
20%
0%
98.0%
73.0%
47.7%
40.5%
44.6%
56.9%
0.0%
71.4%
66.9%
77.2%
100
200
300
400
500
600
700
800
900
1000
TOTAL
SWBS Group



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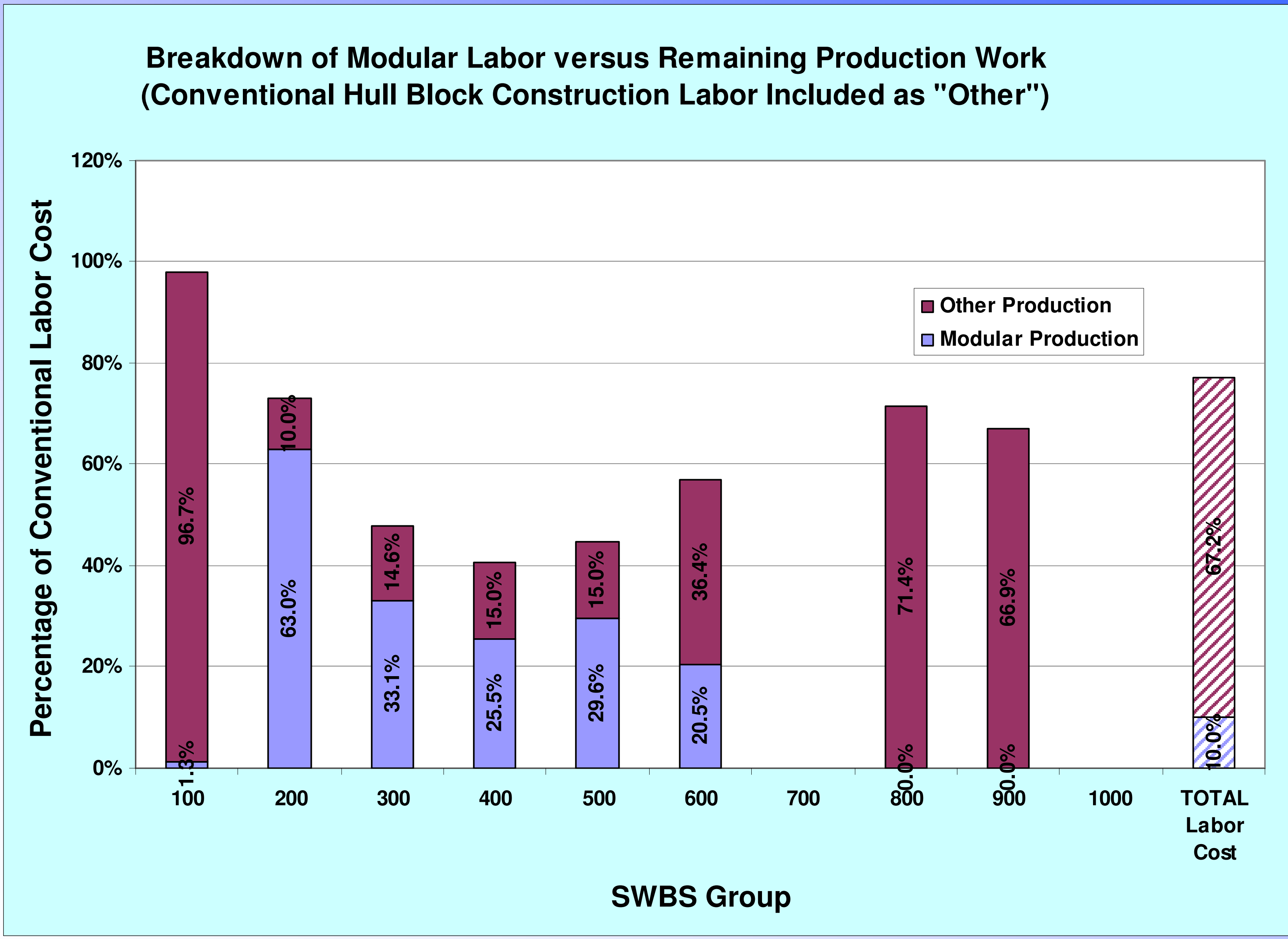
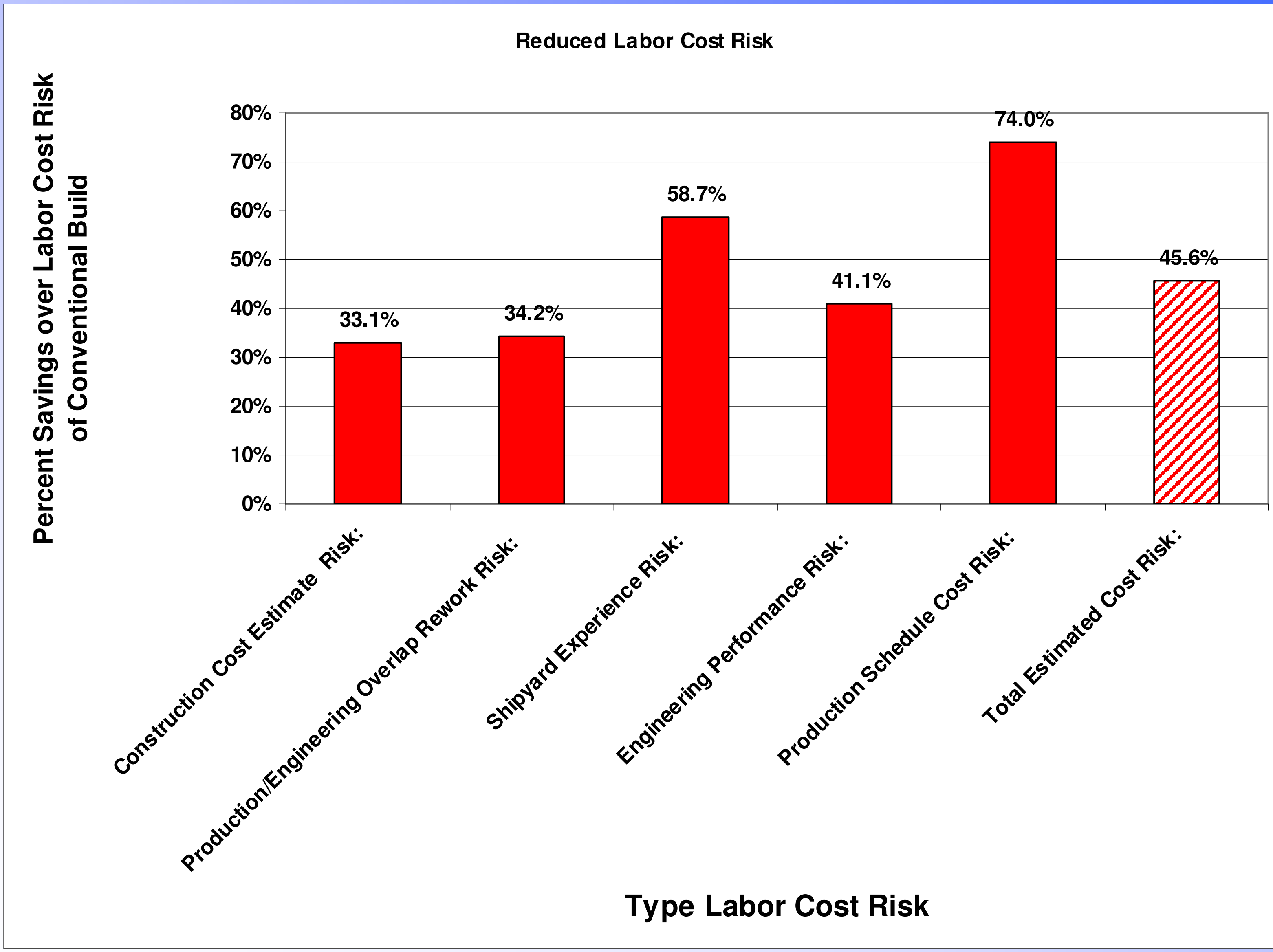

Breakdown of Modular Labor versus Remaining Production Work
(Conventional Hull Block Construction Labor Included as "Other")
Percentage of Conventional Labor Cost
120%
100%
80%
60%
40%
20%
0%
Other Production
Modular Production
96.7%
1.3%
10.0%
63.0%
14.6%
33.1%
15.0%
25.5%
15.0%
29.6%
36.4%
20.5%
71.4%
0.0%
66.9%
0.0%
67.2%
10.0%
100
200
300
400
500
600
700
800
900
1000
TOTAL Labor Cost
SWBS Group


Reduced Labor Cost Risk
Percent Savings over Labor Cost Risk of Conventional Build
80%
70%
60%
50%
40%
30%
20%
10%
0%
33.1%
34.2%
58.7%
41.1%
74.0%
45.6%
Construction Cost Estimate Risk:
Production/Engineering Overlap Rework Risk:
Shipyard Experience Risk:
Engineering Performance Risk:
Production Schedule Cost Risk:
Total Estimated Cost Risk:
Type Labor Cost Risk

Extending ship design and build strategies that advance the use of standard modules can reduce design and construction costs, shorten delivery times, and benefit ship operators with lower maintenance and overhaul costs.

35 Years Serving the Shipbuilding & Repair Industry

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