LIGHTER, FASTER, STRONGER

Approaches to reduce cost of aluminum ship structures

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Overview

- What Alcoa and aluminum bring to the ship builder
- Alcoa's Collaborative Development Approach (ACDA)
- Design for cost and cost modeling
- Results

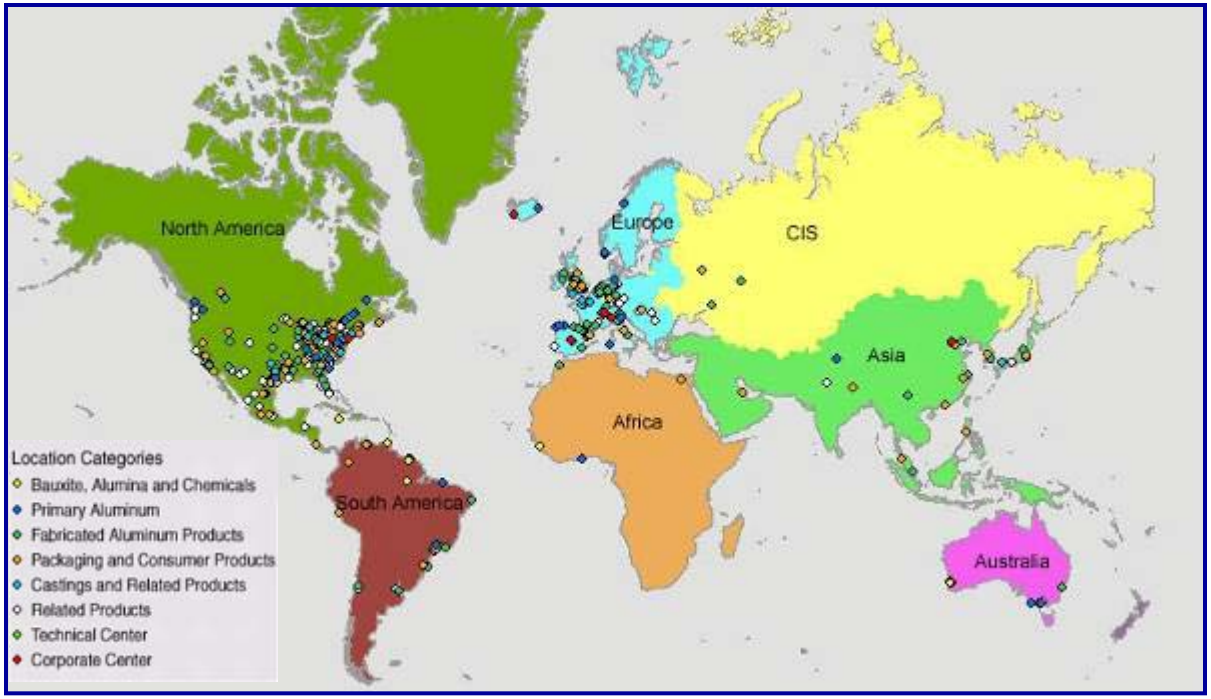
Mining

Alumina

Smelting

Ingot

- Founded in 1888.
- 34 Countries; 450 locations.
- 97,000 Employees.
- $31 Billion Revenue in 2007.
- World-Class Aluminum Expertise.
- Technology Leader.



Aerospace

Automotive

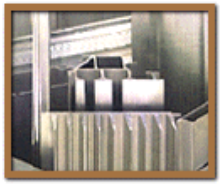
Commercial Vehicles

Defense

Plate

Sheet

Extrusion



Al, SA, Ti Castings

Forgings

Fasteners

Buildings

Technology Leadership

Unparalleled Lightweight Metallics Technology

Metallics database unrivaled by any firm anywhere in the world, the product of more than 100 years of research and engineering expertise

- More than 60 years of experience in developing alloys and products for defense applications

Structural Design Competencies

Critical design tools and competencies recognized in multiple industries, including automotive, aerospace and defense

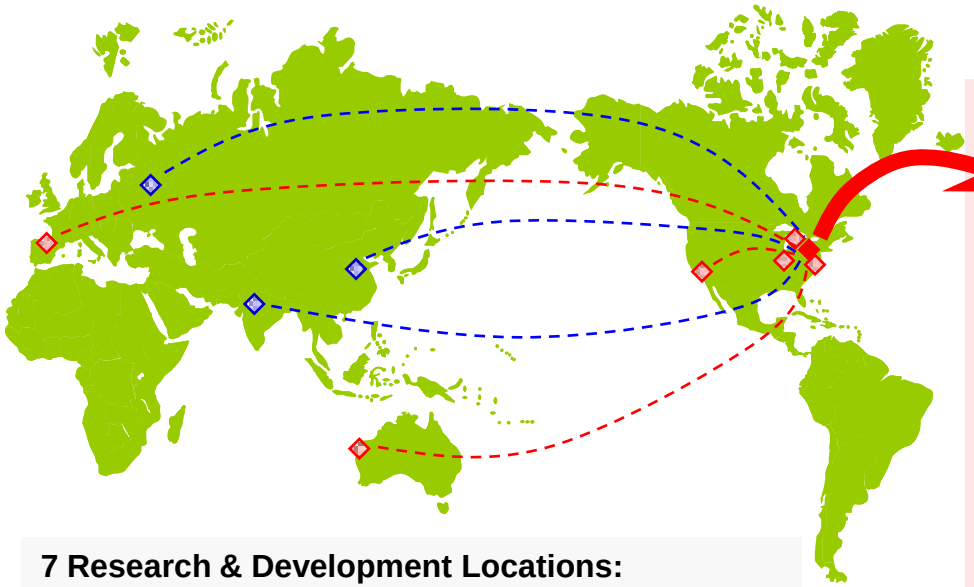
- Design capabilities not limited to a single material or product, but covering a range of solutions, including those that call for integration of aluminum with other materials

Fabrication and Assembly Capabilities

Strong manufacturing pedigree, chiefly born of its work manufacturing integrated structures for the automotive industry

- Extensive experience in producing prototypes ranging from full assemblies to individuals parts
- Manufacturing and assembly issues viewed as critical elements in the design process

Alcoa Science & Technology



7 Research & Development Locations:

- Alcoa Technical Center, PA, USA
- Alicante, Spain (fabrication)
- Carson, CA, USA (fastening systems)
- Crawfordsville, IN, USA (closures)
- Kwinana, Australia (refining)
- Richmond, VA, USA (packaging)
- Whitehall, MI, USA (castings)

3 External Technology Offices:

- Beijing, China
- Moscow, Russia
- New Delhi, India

Alcoa Technical Center (ATC):

- World's largest light metals research facility
- 600 scientists, engineers, technicians & support personnel
- Full range of lab capabilities
- Bench-scale to full production-scale equipment & facilities
- Research, Development and Applied Engineering across all products, markets and processes

ATC Core Capabilities

Product Design / Development

- Product design for:
  - Performance
  - Manufacturing
  - Cost
- Computer-aided-engineering / design (CAE/CAD)
- Design systems / methods / guidelines development
- Material mechanics / characterization
- Validation testing

Basic Science & Metallurgy

- Alloy & temper development
- Mechanical characterization
- Deformation process design
- Numerical simulations (material & process)
- Metallurgical & engineering stds.
- Microstructure characterization
- Constitutive equation dev.
- Thermal process design
- Subscale experimental simulation
- Analytical Chemistry
- Environmental Science
- Surface Science

Manufacturing Systems / Technology

- Control systems
- Measurement systems
- Manufacturing systems analysis
- Statistical methods

Metal Processing

- Melting/recycling
- Metal treatment
- Ingot casting
- Continuous casting
- Process analysis
- Solidification
- Particulate processing

Product Manufacturing

- Metal shaping / forming
- Machining / Metal removal
- Joining & assembly
- Rapid prototyping & tooling
- Engineered Surfaces & Finishes

Advantages of aluminum in marine structures

- Specific strength: high strength-to-weight ratio and density one-third that of steel
- Excellent corrosion resistance in the marine environment:
  - Example: 5xxx series aluminum alloys do not need to be painted
- Weldable
- Formable
- Recyclable
- Ease of machining and ease of handling
- Availability and diversity of semi-finished products to incorporate into ship structures
- Non-magnetic

Alcoa's Navy Initiative

- Alcoa recognizes the resurgence in aluminum ships, and the Navy's past and current challenges with them.
- Alcoa has a strategic initiative to help advance aluminum ship structure materials, design and manufacturing.
- Alcoa's Navy initiative is aimed at improving cost, weight and performance of primary ship structure (hull, deckhouse and structural fittings).
- Alcoa is offering its world-class experience and capabilities:
  - Unmatched lightweight metallics knowledge
  - Proven lightweight high-performance structural design capabilities
  - Design tools, rules and standards
  - Component, sub-assembly and systems manufacturing know-how
- Alcoa's multi-disciplinary approach and collaboration model have delivered tremendous platform advancements in other industries (Commercial and DoD).
- Program pull and support from the Navy and industry are needed to achieve comparable results.

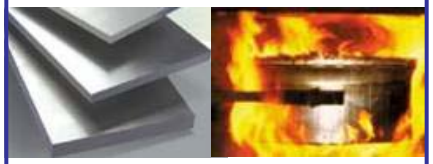
Naval Structures Initiative (NSI)

- First formal engagement and contract activity (in recent history) between Alcoa and the Navy.
- Support research and development of improved lightweight aluminum structures for LCS and other HSVs.
- Alcoa and the Navy created IPTs with members from PEO Ships, NAVSEA 05, NSWCCD, ABS, Primes, Shipyards, and Naval Architects:
  - IPTs were setup in March 2008
  - sub-IPTs for each LCS
  - JHSV being added in 2009

Meeting the Ship Construction Challenge with Alcoa Expertise

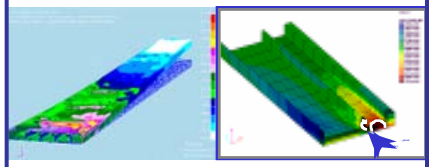
Alcoa can provide the innovations in ship design and construction required by the Navy and industry to create more affordable vessels that will meet mission requirements

Material Knowledge



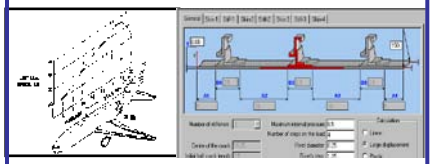
Alcoa is a leader in aluminum alloy research and development

Structural Design



Alcoa is a proven industry partner for aluminum design solutions and can deliver trade studies for alternative designs to the Navy addressing

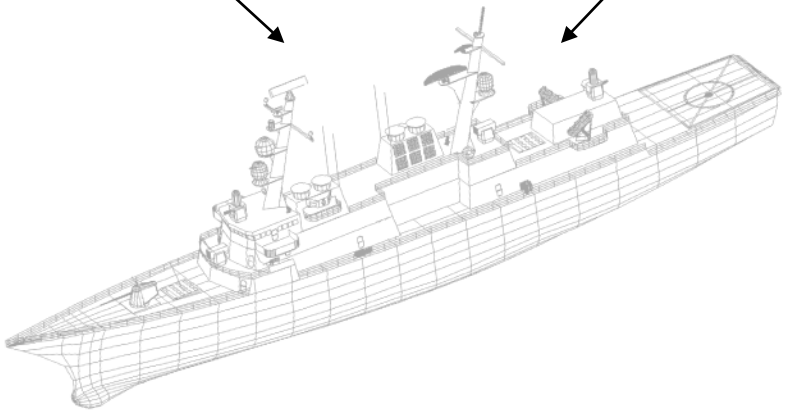
Design Rules & Tools



With decades of design and production experience in aluminum, Alcoa has a breadth of knowledge that can be applied to the optimization of naval design rules and tools

Manufacturing Knowledge

Alcoa's advances in next-generation manufacturing technology



Structural Design Capabilities

- **Alcoa's design technologies have been successfully leveraged across multiple commercial and defense market segments**
  - Rail cars
  - Transportation systems such as bulk trailers and intermodal containers
  - Cars and trucks
  - Commercial aerospace
  - Defense aerospace, land and marine systems
- **Design is driven by customer performance requirements and standards**
  - Alcoa has found that its design competencies and toolkits are fully transferable to other market segments once we learn a customer's performance requirements and standards

Alcoa Joining Process Research

Alcoa is a leader in cutting-edge joining research, cover a broad gamut of technologies and applications

Friction Stir Welding (FSW)

Gas Metal Arc Welding (GMAW)

Magnetrically Impelled Arc Butt Welding (MIAB)

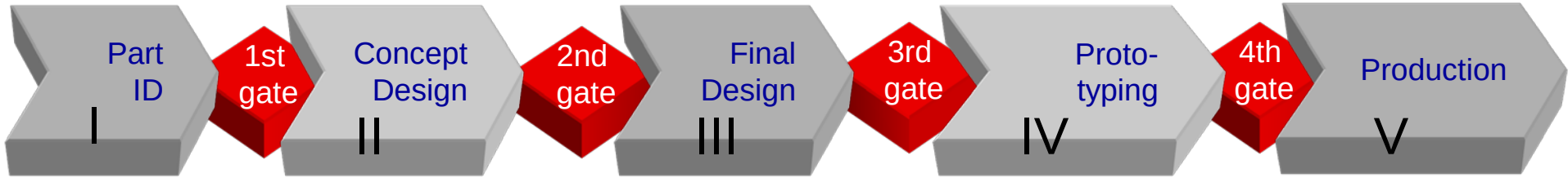
Alcoa Joining Process Research Areas

- **High frequency induction resistance welding**
- **Low and high temperature brazing**
- **High temperature soldering**
- **Magnetically impelled arc butt welding (MIAB)**
- **Gas metal arc welding (GMAW)**
- **Flash welding**
- **Resistance Spot welding with and without adhesives**
- **Riveting (eg., Riv-bonding, blind rivets, self-piercing rivets, etc.)**
- **Adhesive Bonding**
- **Friction stir welding**
  - Conventional
  - Fixed Bobbin tools
- **Friction welding**
- **Laser beam welding with and without wire**
- **Laser-Stir welding**
- **Hybrid GMA/Laser welding**
- **Hybrid Plasma/Laser welding**
- **Cast joining**
- **Double-wire gas metal arc welding**
- **Cold wire assisted plasma welding**
- **High frequency resistance welding**

Alcoa Collaborative Development Approach (ACDA)

- Collaborative IPT Teams (OEM, Alcoa, Military) -

Phase I	-Identify and Select Candidate Assemblies/Components
Phase II	-Develop and Evaluate Conceptual Designs
Phase III	-Finalize Conceptual Designs and Analyses
Phase IV	-Develop and Evaluate Prototypes
Phase V	-Implement Designs in Production



Ex. Activities:

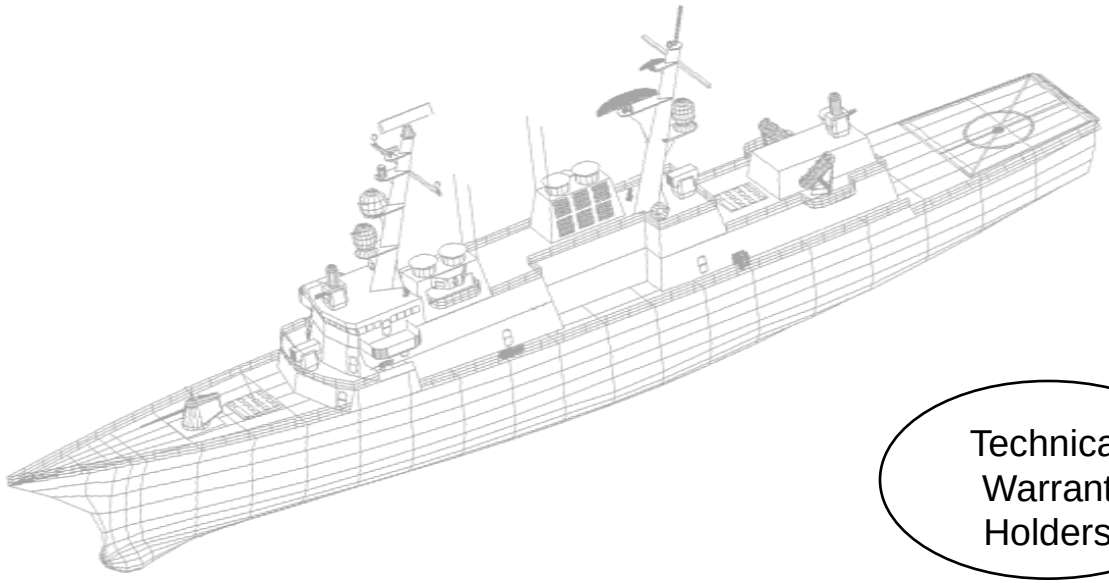
- Opportunity identification
- Gather geometry, packaging, load req's
- Develop concept redesign options
- Prelim. evaluation of conceptual redesigns
- Down-select concepts for further development
- Finalize part redesigns – detailed CAD and analysis
- Evaluate advanced design concepts
- Finalize total costs and plans for prototyping
- Develop prototype part fabrication and test plans
- Produce prototype parts
- Test prototypes and approve for production

Collaboration: Who should be involved

Shipyard

Prime

Naval Architects



Program Office

Ship Design Managers

Technical Warrant Holders

ABS

NSWC

Design for Cost

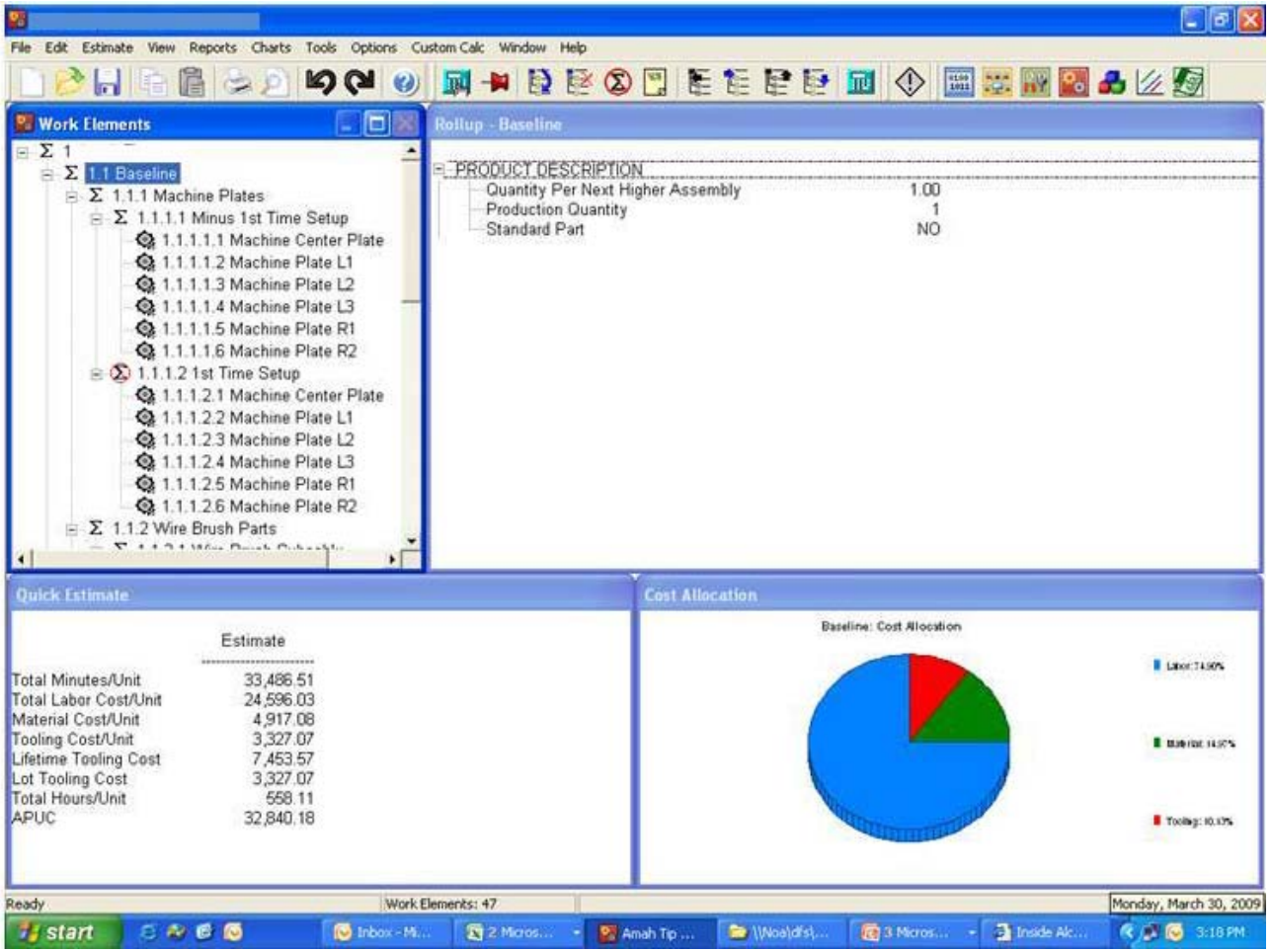
- Once structures are identified as opportunities for cost savings, Alcoa can begin to develop concepts
- Collaboration with the customer(s) identifies requirements and targets
- The baseline structure or component must be defined and agreed upon
- The baseline is then cost modeled
- As concepts are developed they are cost modeled
- The concepts are then evaluated for the above criteria
- This process continues as concepts are downselected and refined

Cost Modeling Methodology

- Manufacturing costs assessments developed with SEER-DFM (www.galorath.com), a commercially available software tool commonly employed in the Aerospace and Defense Industries
  - Parametric cost estimation based upon the application, platform, sizing, material, automation, etc. defined by the user.
  - Develops costs by comparing the user's entries with similar items in a historical database.
  - Provides Recurring Manufacturing Costs for Individual Manufacturing Steps (labor, materials, and tooling)
    - Welding, Machining, NDT, Bolting, etc.
  - Does not provide NRC development costs and labor

Manufacturing Cost Assessment

- Commercial costing software, SEER-MFG (www.galorath.com) employed by major Aerospace and Defense industries
- Piece and process-based cost structure developed
- Processes include machining, surface preparation, fitup and welding operations.



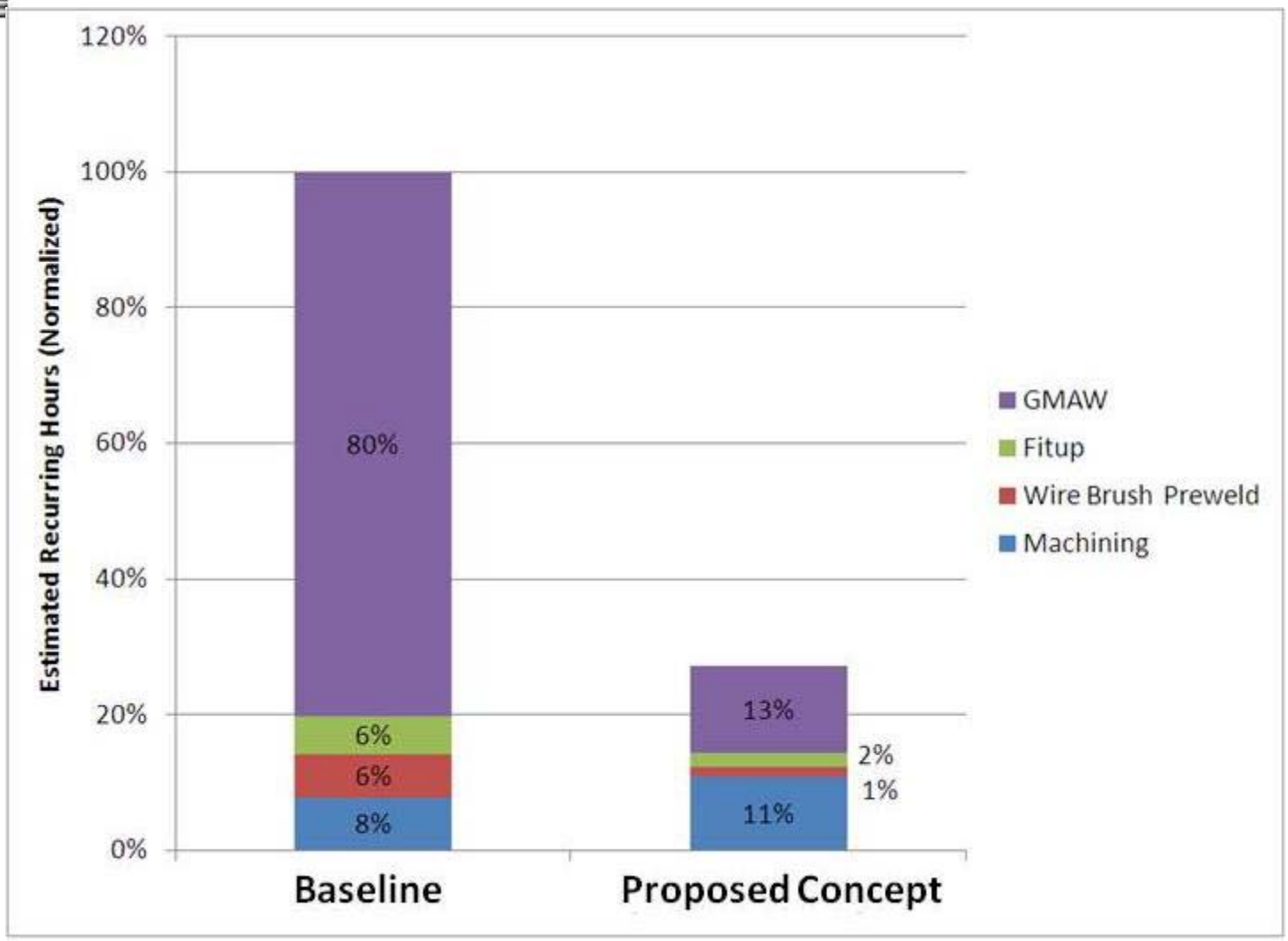
SEER-DFM Overview

- Create or Refine Work Breakdown Structure Based Upon Design & Flowpath
- Define Inputs to Each Manufacturing Step

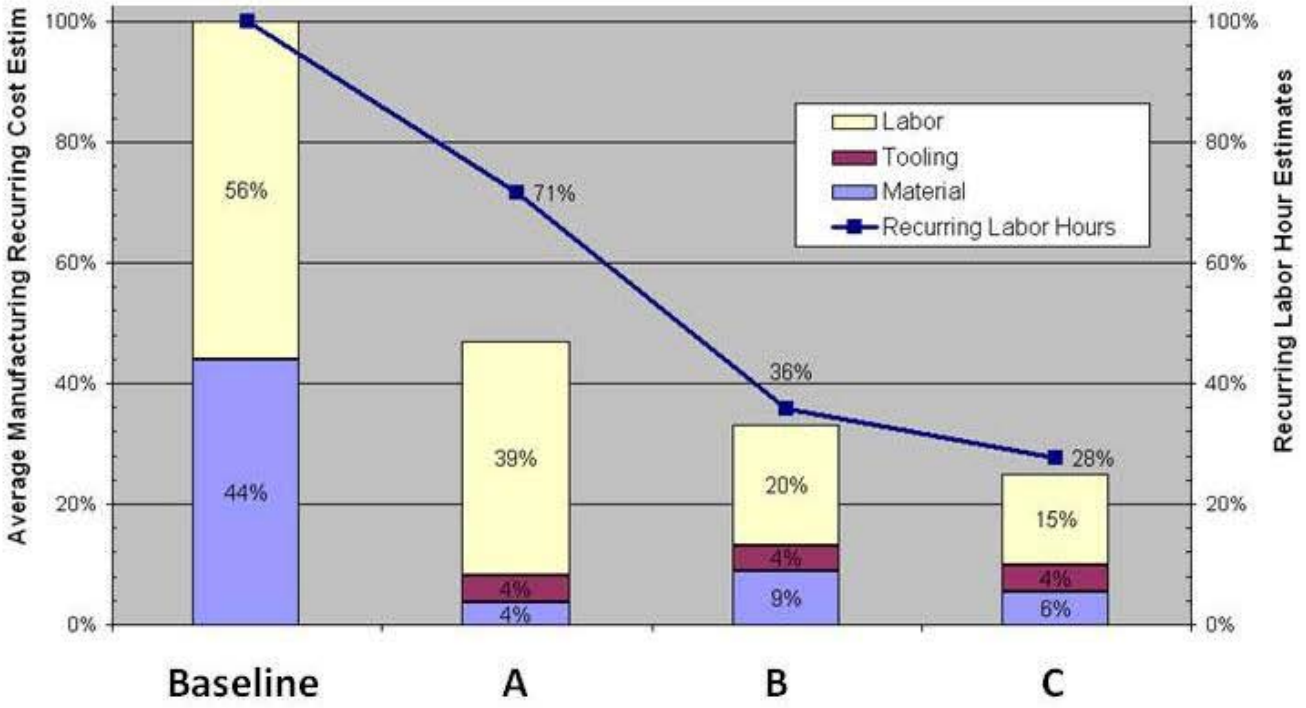
Assembly - MIG Seam Weld

+ PRODUCT DESCRIPTION			
- Quantity Per Next Higher Assembly		1.00	
- Production Quantity		**1,000**	
+ Direct Hourly Labor Rate		**80.00**	
+ Setup Hourly Labor Rate		**80.00**	
- Production Experience/Optimization	**Hi**	Hi	**Hi**
- Product Classification	**Hi-**	**Hi**	**Hi+**
+ MECHANICAL ASSEMBLY		NO	
+ WELDING		YES	
- Parts to Join	**1**	**1**	**1**
- Weld Type		Arc, Gas Metal Arc, MIG, TIG	
- Material		Aluminum Alloy	
- Material Thickness (in)	**0.400**	**0.400**	**0.400**
- Seam Length (in)	**4.00**	**4.00**	**4.00**
- Seam Width (in)	**0.00**	**0.00**	**0.00**
- Number of Passes	1	1	1
- Mechanization	**VLo**	**VLo**	**VLo**
- Material Cost Per Welded Assembly (Optional)		0.0000	
- Tooling Cost (Optional)		0.00	
- Tooling Amort. Quantity (Optional)		0	
- Other Cost (Optional)		0.00	
+ BRAZING		NO	
+ RIVET/STAKE		NO	
+ ADHESIVE BONDING		NO	
+ ADDITIONAL ITEMS		NO	
+ MANUFACTURING DESCRIPTION			
- Set-up Complexity	Nom	Nom	Nom
- Tooling Complexity	Nom	Nom	Nom
+ OPTIONAL COST DESCRIPTION			
- Set-up Amortization Quantity (Optional)		**1**	

An example


120%
100%
80%
60%
40%
20%
0%
Estimated Recurring Hours (Normalized)
80%
6%
6%
8%
13%
2%
1%
11%
Baseline
Proposed Concept
GMAW
Fitup
Wire Brush Preweld
Machining

Cost Estimates and Concept Evaluation



- Do any of the concepts meet your cost targets?
- Are there other factors that need to be considered such as weight or repairability?

Total Ownership Cost

- True ship costs extend beyond the cost to build the ship. These include:
  - Cost to maintain the ship structure including manpower costs
  - Cost in fuel to operate the ship
  - For commercial vessels, costs incurred by heavier than necessary structures
    - Hedlund-Åström 2009 in a life cycle cost analysis shows a 50% weight savings design for a Ro-Ro superstructure by switching to aluminum
    - Weight reduction used as increased payload resulting in a break-even point of around 5 years of operation
  - Costs to dispose of the vessel
  - Environmental factors
- Ship designers and builders should use aluminum's advantages to reduce life cycle cost
- These life cycle factors can impact the shipbuilding costs as it can determine which cost saving concepts are selected for application

Results

- Each opportunity identified that required a solution in cost has resulted in 50-70% savings in recurring manufacturing cost
- Each opportunity identified that required a solution in weight has received between 15-60% savings in weight
- Immediate payoffs: solutions are being inserted onto LCS-3 and LCS-4

Summary

- Alcoa recognizes the resurgence in aluminum ships, and the Navy's past and current challenges with them
- Alcoa has a strategic initiative to help advance aluminum ship structure materials, design and manufacturing
- Alcoa is offering its world-class experience and capabilities:
  - Unmatched lightweight metallics knowledge
  - Proven lightweight high-performance structural design capabilities
  - Design tools, rules and standards
  - Component, sub-assembly and systems manufacturing know-how
- Alcoa's multi-disciplinary approach and collaboration model are delivering results saving costs and weight for shipbuilders