



# Steel and Steel Processing to Benefit Ship Construction

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# Presentation Objectives

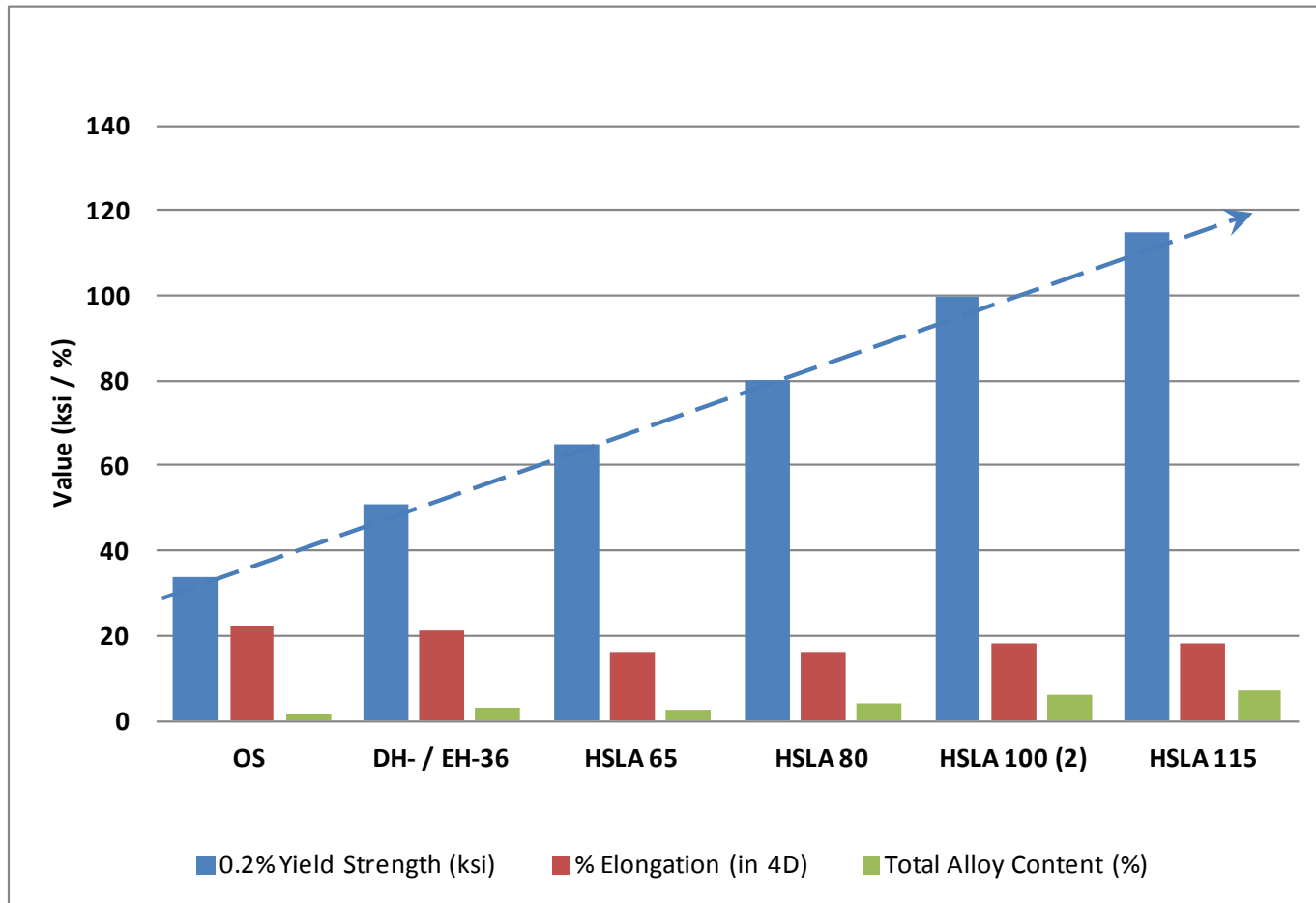
- **Trends in Shipbuilding Steel Alloy Development**
  - Development of Higher Strength Alloys
  - CRES Steels
- **Thin Plate Distortion**
  - Distortion Mitigation Technologies
- **Related Technologies**
  - Fabricated Components
  - Metallic Sandwich Structures
  - Rapidly Tooled Casting Solutions

# Steel Alloys – Primary Material in Ship Construction

- **Low carbon steel alloys account for the majority of the mass of most modern U.S. naval assets**
  - CVN 77: 50,000 tons of steel (displacement  $\approx$  97,000 tons)
  - VCS: 4,500 tons of steel (displacement  $\approx$  7,800 tons)
  - DDG-51: 3,500 tons of steel (displacement  $\approx$  8,900 tons)
- **Common forms used in ship construction**
  - Plate / Sheet
  - Rolled shapes
  - Forgings
  - Piping
  - Castings

Ref.: [http://www.steel.org/en/The%20New%20Steel/~/\\_media/Files/AISI/Steel%20Markets/fs\\_backbone\\_defense\\_oct08.ashx](http://www.steel.org/en/The%20New%20Steel/~/_media/Files/AISI/Steel%20Markets/fs_backbone_defense_oct08.ashx)

# Steels for Ship Construction Trending Toward Improved Mechanical Properties



Ref: ABS Steel Vessel Rules / ASTM specifications / NMC data

# Benefits of Improved Mechanical Properties in Steel Alloys

- **HSLA steels offer several advantages compared with traditional carbon steels**
  - Higher strength with good ductility
    - Microalloying yields a fine-grained microstructure
    - HSLA alloys exhibit good toughness
  - Good formability at room temperature
    - Hot forming requires careful control to avoid strength degradation
  - Good weldability with most conventional welding methods
    - Lower preheat requirements
  - Good corrosion resistance
    - Ferritic microstructure improves general corrosion resistance

# Steel Alloy Development Trends

# HSLA-115 Implementation with NNS for CVN 78

- **NMC-led IPT developed and executed a material certification test plan for HSLA-115 use on CVN 78 for topside weight reduction**
  - **132 tons topside weight reduction**
  - **HSLA-115 approved for use by NAVSEA**
  - **NNS has procured ~2000 tons of HSLA-115 for CVN 78 construction**



540 x 110-inch  
HSLA-115 Plate  
Produced by  
ArcelorMittal USA



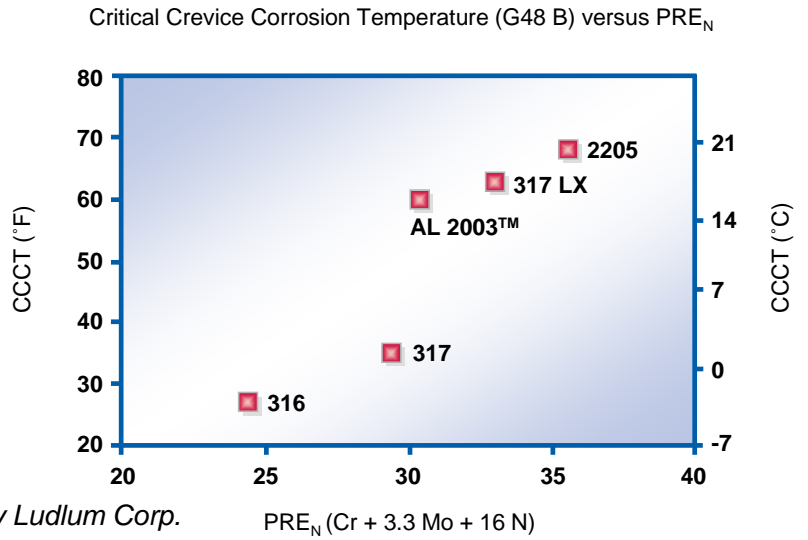
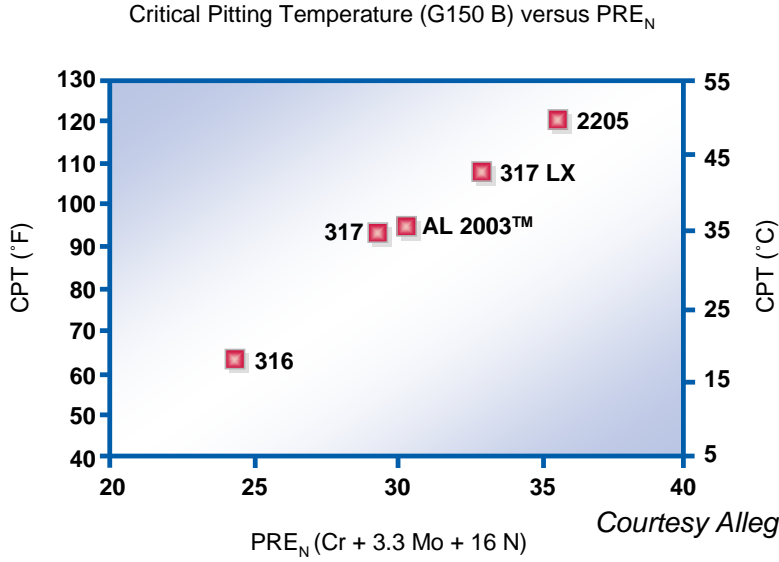
*Courtesy ArcelorMittal*

# Corrosion-Resistant Steels Developments

- **Duplex Stainless Steels**
  - ATI 2003
  - ATI 2205
- **Precipitation Hardening Steels**
  - 15-5PH Modified
  - 13-8PH
- **Other High Performance Steels**
  - AI6XN
  - 10-Nickel

# Duplex Stainless Steel – ATI 2003

ATI 2003 has higher strength/better corrosion resistance with comparable price to 316/316L.



Courtesy Allegheny Ludlum Corp.

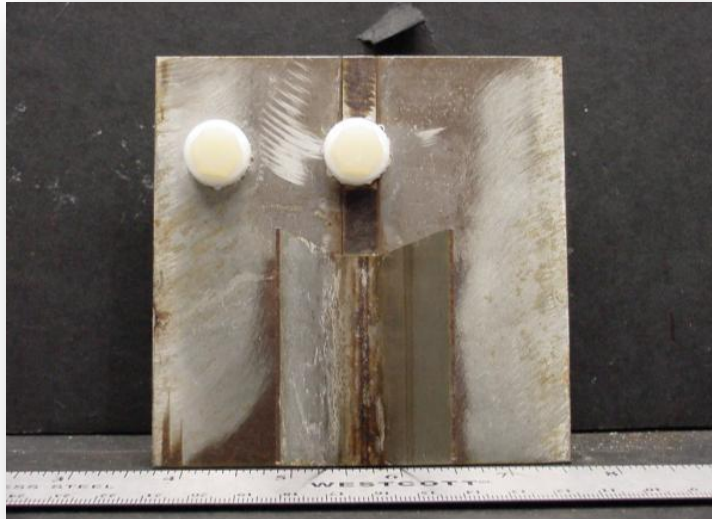
ATI 2003 UNS S32003 Specified Room Temperature Tensile and Hardness Properties						
Product Form	Thickness Inch	Min Tensile Properties			Max Hardness	
		YS, ksi	UTS, ksi	Elong, %	Brinell	Rockwell C
Sheet	≤0.187	70	100	25	293	31
Plate	>0.187	65	95	25	293	31



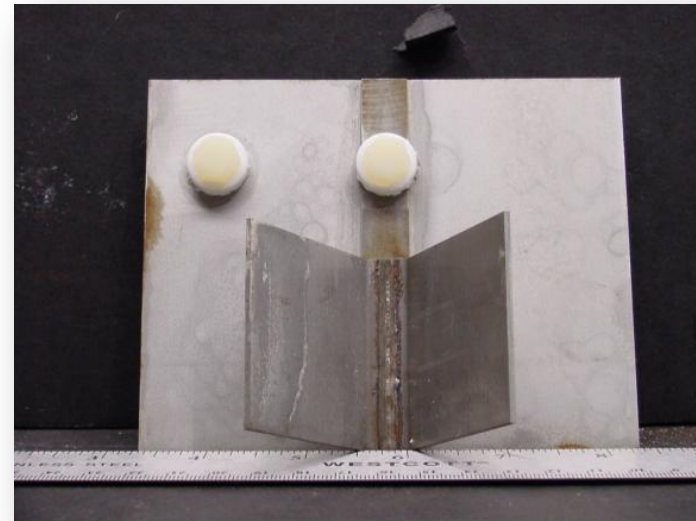
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# GM 9540 Accelerated Corrosion Testing (180 cycles)

316L Stainless Steel



CRES 2003 Lean Duplex SS



**Minimal corrosion was found in any of the CRES 2003 configurations after testing for 180 cycles in salt fog**



HSLA-100

# 15-5PH Modified Precipitation Hardening Steel

- “Lean” version of standard 15-5PH with carefully controlled thermal-mechanical processing during forging process
- Excellent toughness and corrosion performance
- Available as forged bar and plate

Modified 15-5PH Forgings Room Temperature Tensile and Toughness Properties						
Heat Treat Condition	Thickness Inch	Min Tensile Properties			Min Toughness	
		YS, ksi	UTS, ksi	Elong, %	DT, ft-lb	$K_{JIC}$ , ksi- $\sqrt{\text{in}}$
H1125	≤ 8.0	120-145	135	14	300	160
H1150	≤ 8.0	105-130	135	14	400	160



**No evidence of pitting or galvanic corrosion was observed in 15-5PH / NiAlBrz coupled test specimen after 120-day immersion test**



# Thin Plate Distortion Mitigation

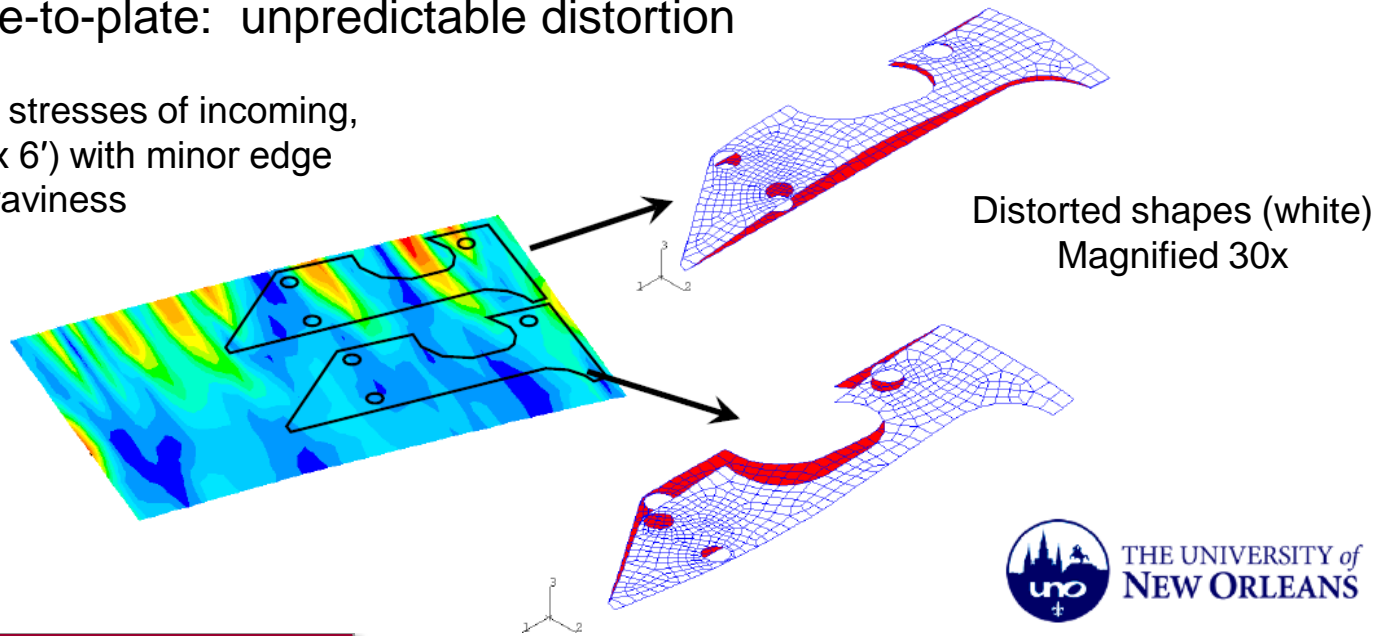
# Thin Panel Distortion Challenges

- **With the availability of higher strength steels, the opportunity exists to reduce panel thickness in many structures to save weight**
  - Assuming other design and performance requirements (toughness, ballistics, etc.) can be met for the given application
  - Many of the newer ship classes contain >60% steel plates that are <3/8-inch thick
- **As usage of thinner plates increases, thin-plate distortion issues can adversely affect ship affordability**
  - Plates received with distortion / warpage
  - Plates received with high residual stresses
  - Distortion introduced during welding

# Panel Plate Distortion

- Thin ( $\leq 3/8''$ ) plates for panel construction and parts cut from thin plate can easily distort, resulting in rework and lower accuracy
- Variation in residual stresses
  - Within a plate: distortion varies from one cut to another
  - Plate-to-plate: unpredictable distortion

Typical residual stresses of incoming, flat plate (10' x 6') with minor edge waviness

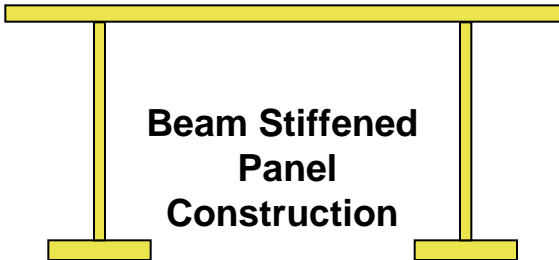


# Plate and Cutout Distortion

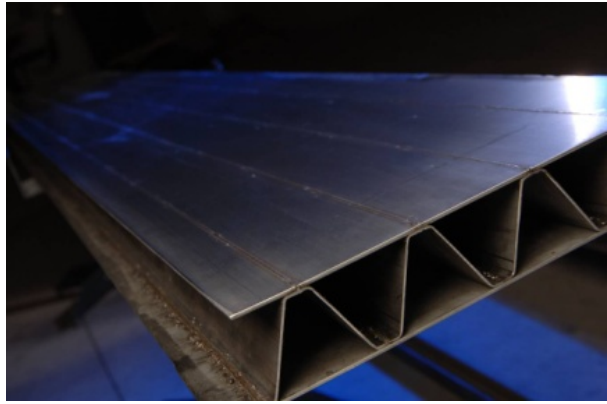
- **Other work has shown that increased plate width results in higher residual stresses along plate edge**
  - Increased distortion in fabricated shapes
  - 60% increase in edge residual stresses in 120" vs. 72" width
- **NMC, Ingalls and UNO have recently initiated a Navy ManTech project to address several aspects of thin plate distortion**
  - Develop technical specification for sourcing plates with desired shape/flatness to meet shipyard requirements
  - Modify plasma cutting sequence and parameters to reduce distortion and improve cut part accuracy thereby reducing rework
  - Reduce or modify residual stress distribution in plates to reduce distortion and improve cut part accuracy thereby reducing rework

# Other Relevant Technologies

# Engineered Metallic Sandwich Structures



- Increased Stiffness
- 20–50% Less Weight
- Less Complex Outfitting
- More Compact Profile
- Modular Construction
- No External Stiffeners
- Girder Spacing Increased

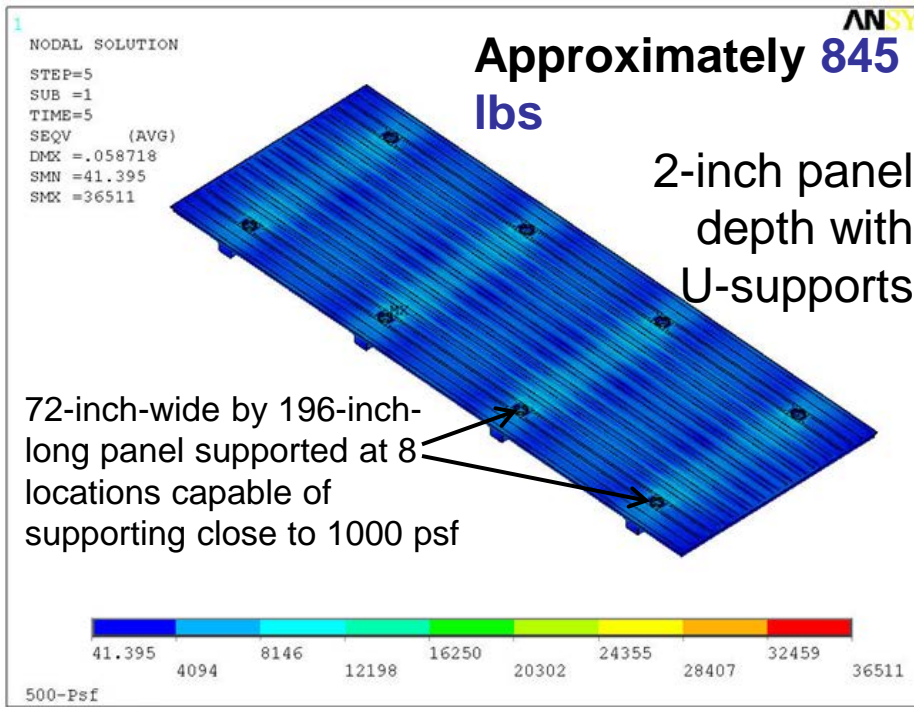


Photos Courtesy ATS

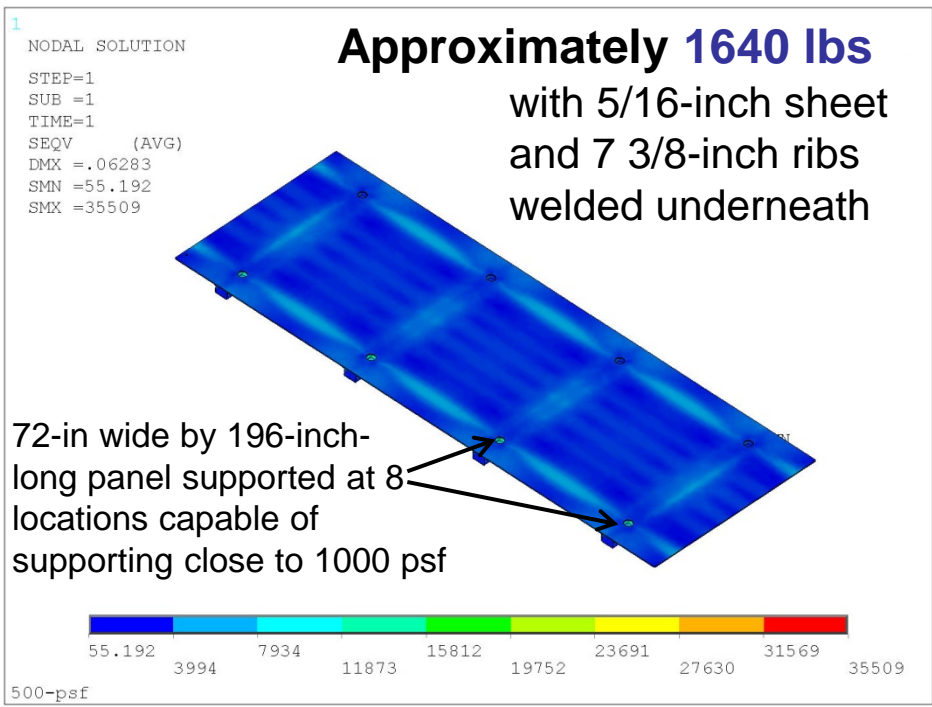
# Metallic Sandwich Panel Designs are Lightweight, Compact and have High Structural Stiffness

- By using high strength materials, metallic sandwich panel designs have a high strength to weight ratio
- Comparable sheet steel panel designs are heavier

## Sandwich Panel



## Plate and Stiffener



# HLAW Fabricated Tee-Beams



HSLA-80 HLAW Beam  
Procedures Qualified by  
ABS on NMC Project

## Applications:

Built-up Tees (Navy Alloys DH 36, HSLA 65/80) – can apply to stiffeners and other welded shapes. Also can be used for butt-welds and stiffener to plate welding.

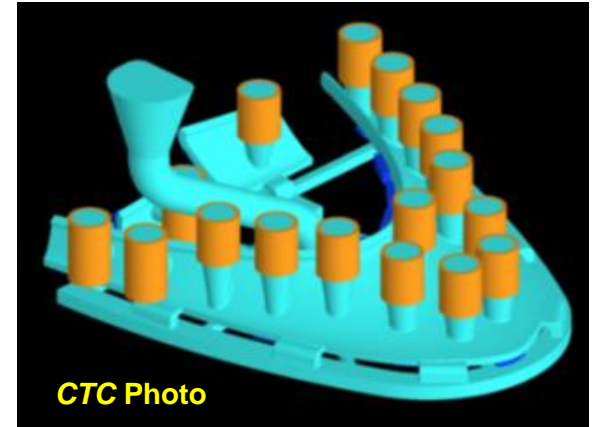
## Benefits:

- HLAW provides significantly reduced distortion
- Improved accuracy of fabricated shapes reduces assembly and fit up times (20–30%)
- Reduced section weight for stiffeners (20–50%) depending on alloy selected
- Provides flexibility and can reduce inventory for stiffeners
- Use of higher strength materials HSLA 80/65 over DH 36 may provide weight savings
- Applied Thermal Sciences and American Tank and Fabrication (AT&F) capable of HLAW beam fabrication in U.S.

HLAW provides reduced distortion, improved fit-up, faster throughput and design flexibility

# Innovative Rapid Tooling Casting Technologies

- Printed sand mold technology has become a viable option for producing complex casting geometries without the need for expensive tooling
- Ideal for prototype castings or low-volume runs where cost of tooling is often prohibitive
- Printed directly from a 3D solid model
- Larger molds produced by assembling inter-locking segments



# Printed Sand Casting Molds

- Example: LCS waterjet inlet tunnel leading edge
  - Horseshoe shape: 12.5' x 5'
  - Legacy design: weld 13 cold-formed steel plates
  - New design: three-piece casting
- Printed sand mold
  - Provisions for chills, risers & metal delivery system
  - Printed in two days by ProMetal®
- Benefits
  - Rapid turnaround
  - No pattern – economical for small-lot runs
  - Mold easily modified
  - Produce more complex shapes



Photo courtesy of ProMetal

Printed sand mold with provisions for chills and other casting features

CTC Photo

Three-piece WjIT casting (some casting rigging still attached)

# Future Development Activities

- **Continued development of higher strength HSLA Steels**
- **Increased use of CRES steels for corrosion-prone applications**
- **Improved consistency of thin plates from steels mills**
  - **Uniformity in stress levels across width**
  - **Plate-to-plate consistency**
- **Increased use of engineered structures using sandwich panel construction**
- **Development and application of improved coatings for corrosion resistance and survivability**

# Questions?