Low-Cost Friction Stir Welding of Aluminum for Littoral Combat Ship Applications

Objective: Develop a prototype low-cost, transportable FSW machine for stiffened panel production at LCS shipyards

8th Int'l Symposium on FSW

18-20 May 2010

Timmendorfer Strand, Germany

On behalf of the LC-FSW IPT

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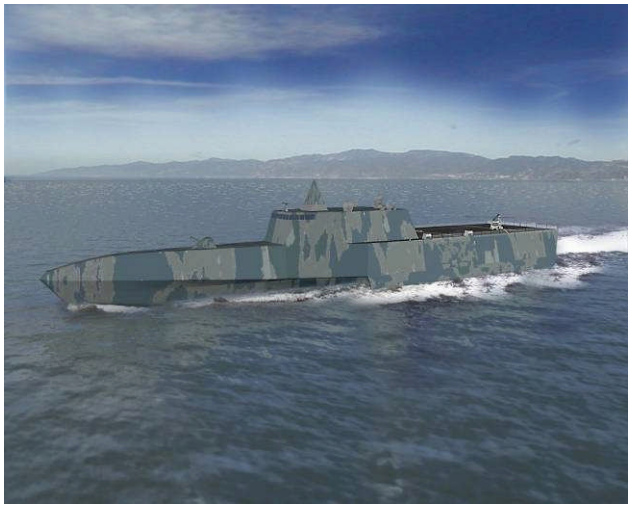
Project Background

- The Littoral Combat Ship (LCS) program currently has two teams, headed by lead system integrators Lockheed Martin and General Dynamics

Lockheed Martin Team

Freedom (LCS 1) on acceptance trials, August 2008
Photo courtesy of Lockheed Martin Team

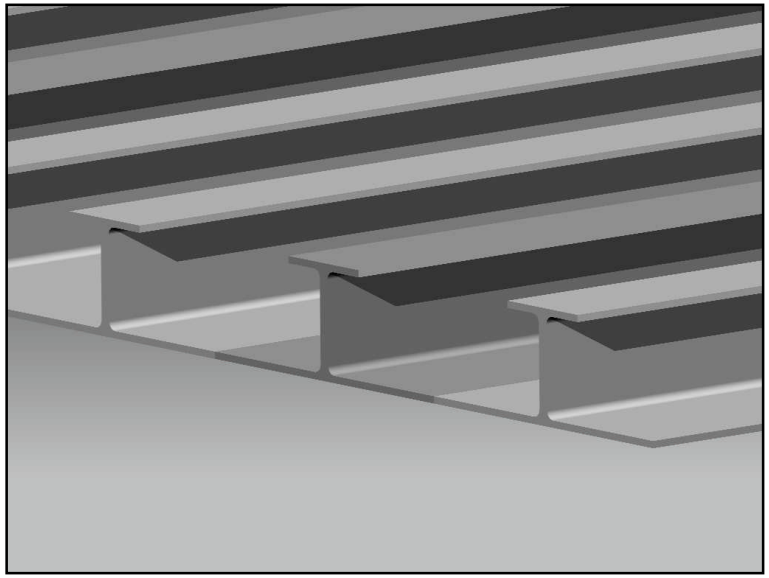
General Dynamics Team



LCS 2, the future USS Independence concept drawing; keel laid at Austal USA, 19 January 2006

Program Background

- The Lockheed Martin LCS design makes extensive use of stiffened aluminum panels for construction of the ship's superstructure
- These panels are built up from extruded aluminum shapes using friction stir welding (FSW) as the joining method

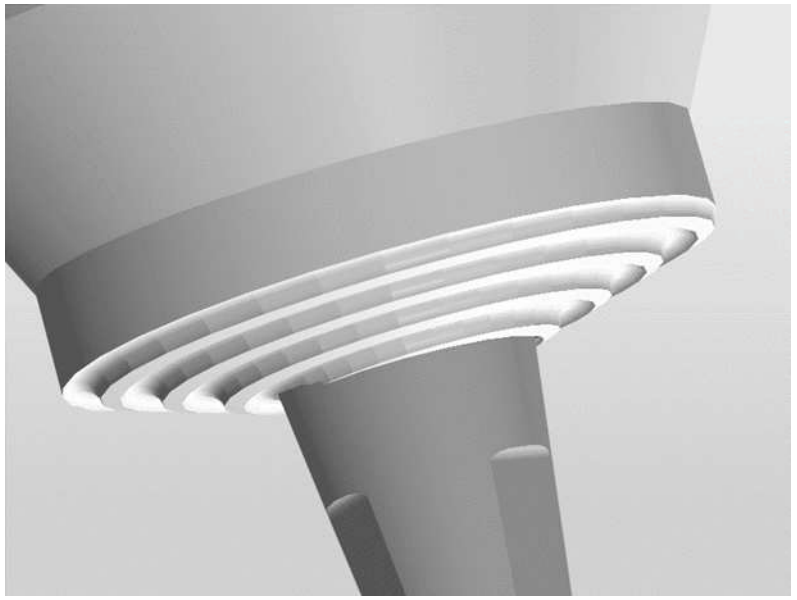


Program Background

- **Problem Statement**
  - **Current FSW machines for production cost >$1M**
    - **Multiple powered axes**
    - **High process forces**
    - **General-purpose equipment is overkill for many shipyard uses**
  - **High capital and recurring costs require multi-shift, continuous machine operation and an extensive backlog of work to justify the expense**
  - **Off-site production by FSW suppliers limits panel size by transportation method and makes net-shape production difficult**

Fixed-Geometry Bobbin Tools

- **Combination of the scrolled shoulder with the tapered profile allows embedding of the shoulder in the workpiece**
- **Scrolled shoulder + tapered profile = improvements in tool performance**
  - **variable shoulder depth**
  - **fixed-geometry bobbin**
  - **thickness mismatch**
  - **complex workpiece contour**

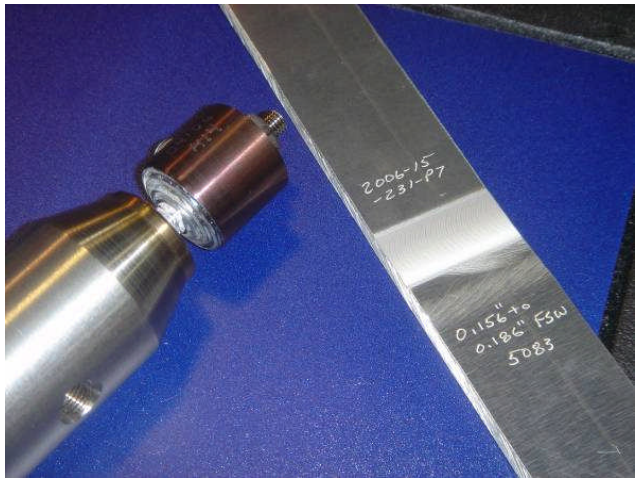


Tapered shoulder design, patented by *CTC* (US patent 6,669,075)

Fixed-Geometry Bobbin Tools

- **"Self-reacting" tools require actuation of the pin relative to the shoulder, adding a machine axis**
- **The tapered shoulder design makes practical a fixed-geometry bobbin tool**
  - **Usable on all welding machines, machine tools**
  - **Simple operation – adjust gap to accommodate plate variation**

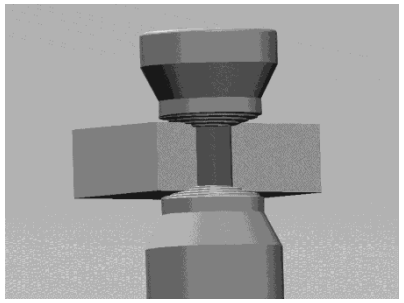
Fixed-geometry bobbin tool



Weld between 4mm and 4.75mm 5083 Al

Program Background

- **Breakthrough Technology**
  - **New welding tool technology makes possible a very low-cost, transportable welding machine**
    - **Fixed geometry bobbin tool**
    - **New equipment design approaches**
  - **Now possible to produce a very low-cost machine for welding extrusions**
    - **Single-purpose machine—single axis of motion**
    - **No load transfer to floor—no foundations to install**
    - **Minimal instrumentation**
    - **Transportable—within yard or between yards**
    - **Produces very large panels—no longer "truck limited"**
    - **Provides most of the stir welding that shipyards need**



Bobbin FSW Tool

Program Approach

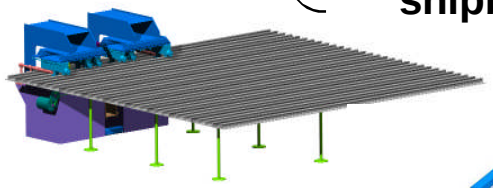
Navy ManTech project to develop and demonstrate Low-Cost FSW

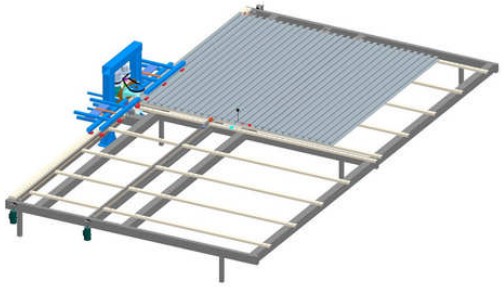
Phase I 8/06 – 8/07

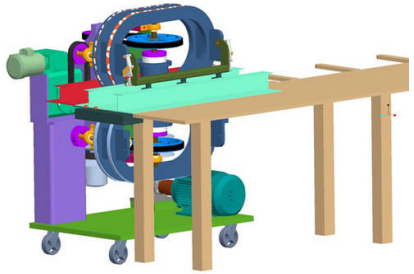
- Design and develop drawing package for low-cost FSW system
- Work with extrusion suppliers to reduce geometric variability in extrusions
- Characterize FSW joints produced in representative materials

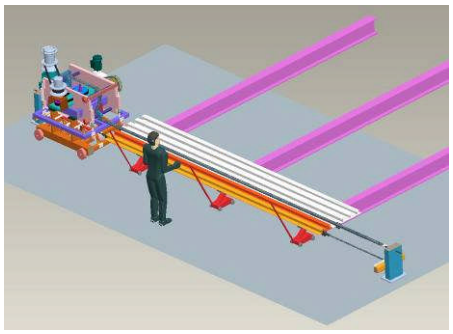
Phase II 8/07 – 5/09

- Build and integrate welding system
- Test and demonstrate the welding system at NMC, then transition to the target shipyard
- Demonstrate fabrication of production panels at the shipyard
- Make the machine design and test data available to DoD contractors free of charge so duplicate systems can be implemented in shipbuilding or other industries







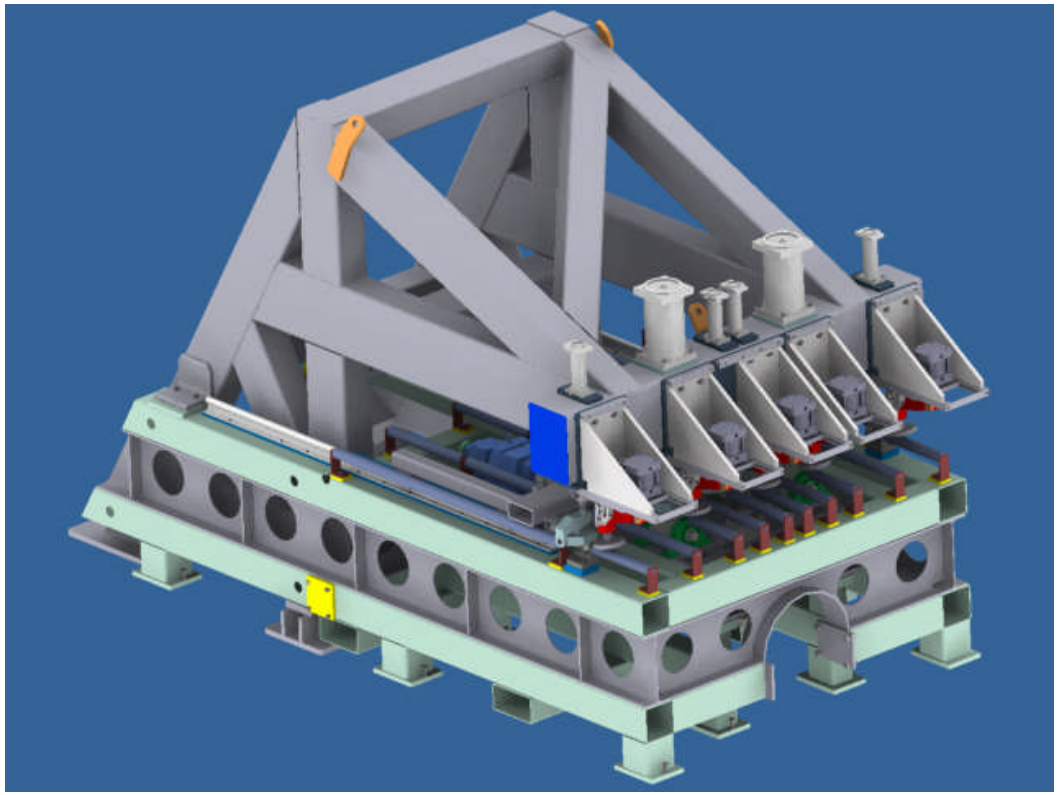


Machine Concepts

LOCKHEED MARTIN MMC Bollinger Shipyards, Inc. ONR Science & Technology NAVY MANTECH CTC Concurrent Technologies Corporation

Phase I Results

- Developed system requirements, conceptual design and detail design
- Demonstrated welding process, confirmed joint properties, welds made at up to 1 meter/min in 5xxx alloys
- Established economic justification, explored several production scenarios
- Evaluated conventional and wide extruded materials



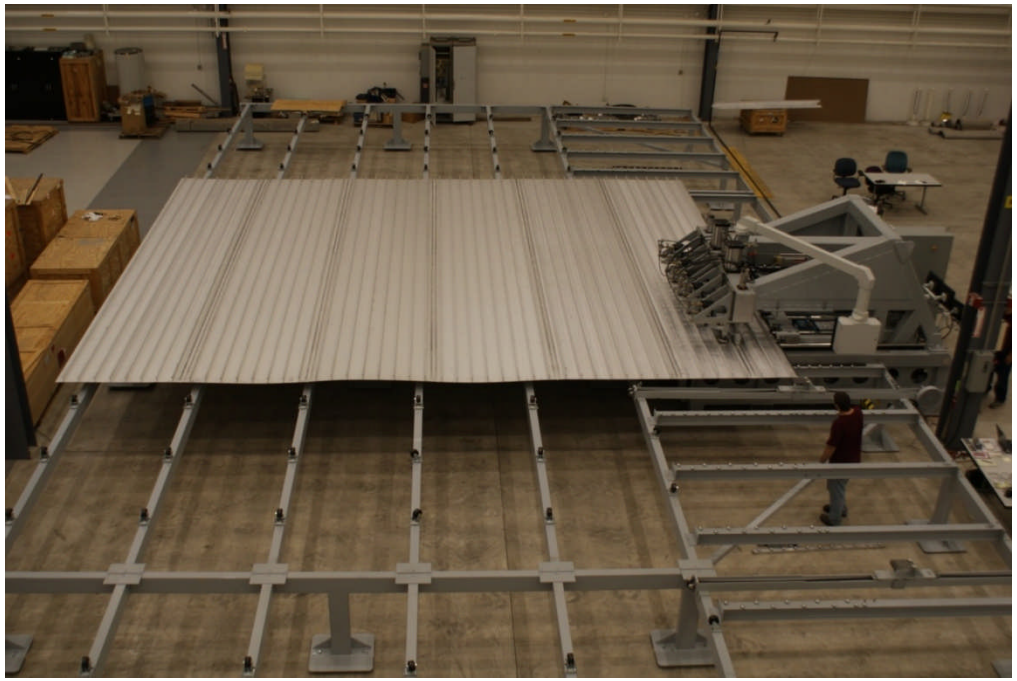
Phase I machine design

Low-Cost FSW System

Capability Summary

- Fixed machine – traveling workpiece
- Workpieces up to 12-meters long and 9-meters wide
- Workpieces from 3-mm thick up to 12-mm thick
- Extrusions up to 1.65-meters wide
- Minimal foundation requirements

Detail Design and Construction by Nova Tech Engineering, Lynnwood, WA



Phase II machine design
- 1.6-m wide aluminum 5083 extrusions
- 5.5 mm thick, 12-m wide, 8-m long panel
- Welding at 0.5 m/min welding speed

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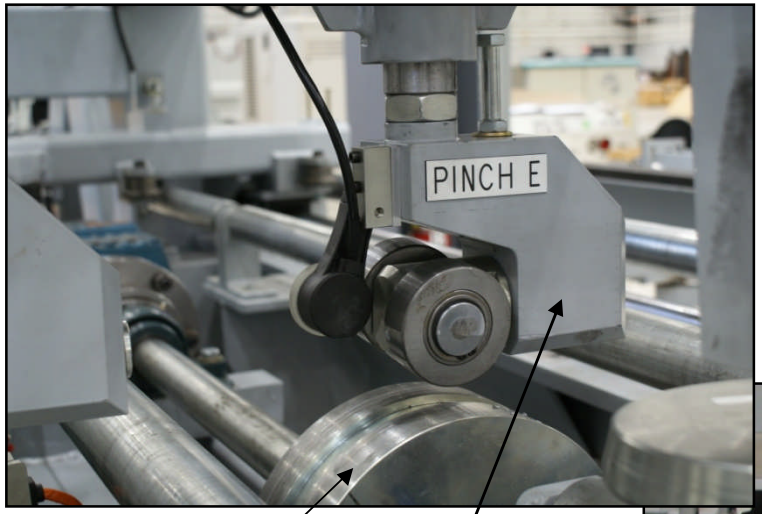
Low-Cost FSW System

Welding 1.6-m wide aluminum extrusions, 5.5mm thick

Setting up for 200-mm wide aluminum extrusions, 5mm thick

Low-Cost FSW System Design



- **Utilizes rollers to drive and align workpieces**
- **Minimizes powered axes (bi-directional travel, spindle rotation)**

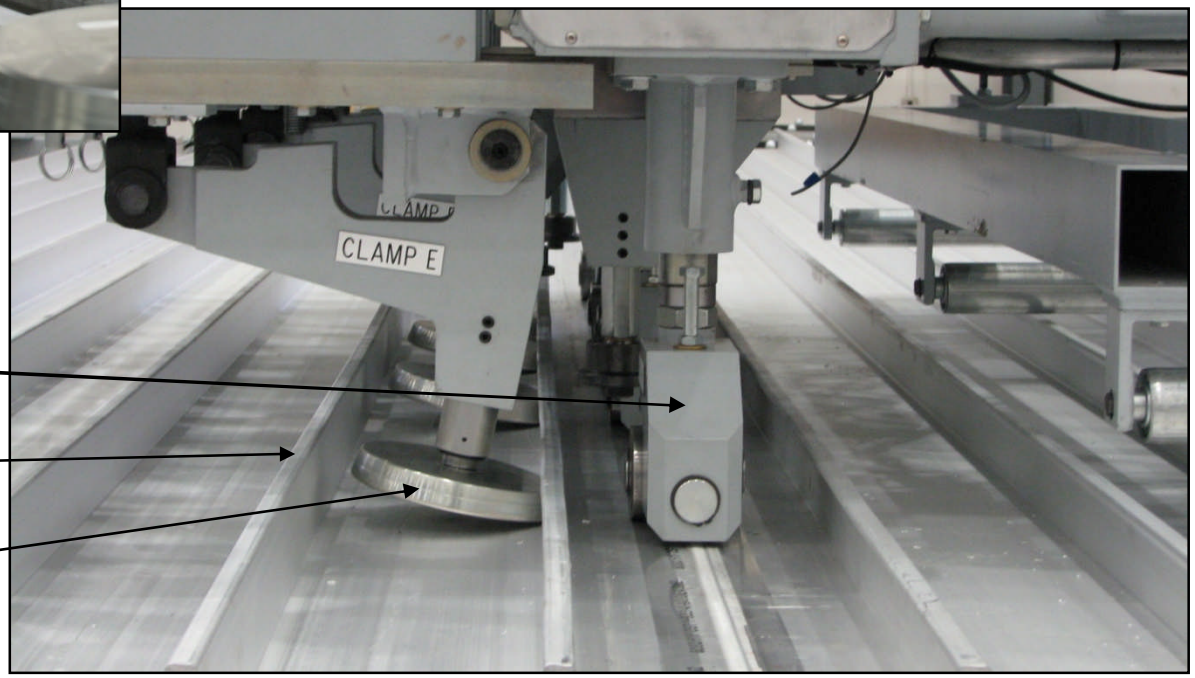
Drive rollers (2)

Pinch rollers
(2 high force, 4 low force)

Aluminum extrusion

Clamp roller (5)

Shown with 1.6-m wide extrusions



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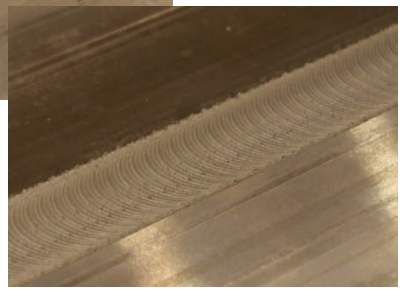
Low-Cost FSW Machine Checkout

- **Bead-on-plate weld, simulating 172 sq. m panel with 9-m outboard of spindle.**

Back side weld crown



Spindle side weld crown

- **1.6-m wide 5083 aluminum extrusions**
- **5.5 mm thick, 9-m wide panel, with additional weight to simulate a 172-sq m panel**
- **Welding at 0.5 m/min welding speed**

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Customer Benefits

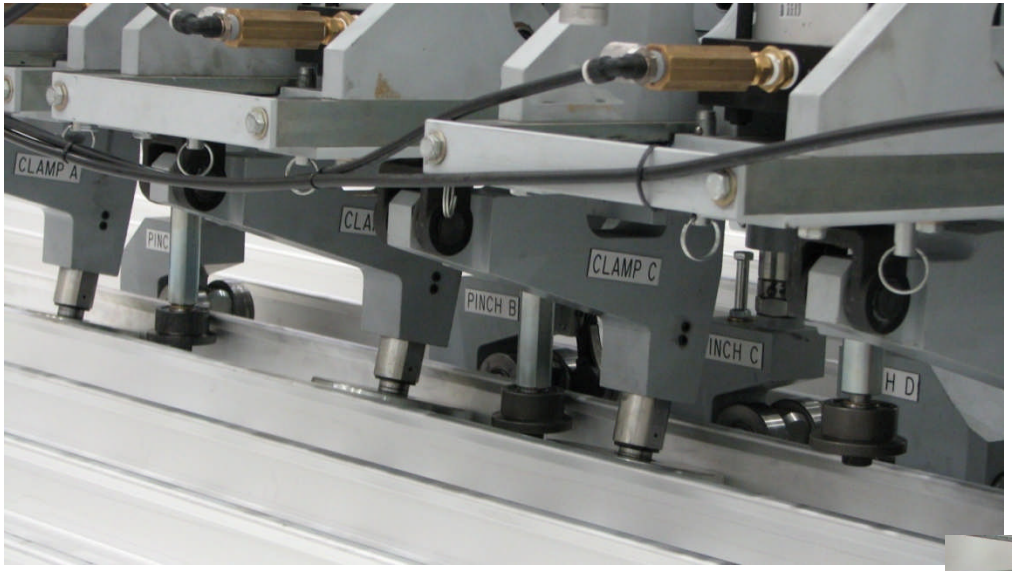
- **Locating FSW at Shipyard**
  - Full-size panels, not sized for road transport
  - Reduced waste, net-size production
  - Reduces transportation costs
  - Reduces arc welding for panel assembly, improving quality, reducing distortion, and reducing production labor costs
- **Low-Cost FSW Machine**
  - Enables positive business case for FSW adoption for many applications requiring stiffened aluminum panels
  - Produces welds by a procedure that will be certified by ABS and NAVSEA
  - Production machine design available through DTIC for DoD contractors

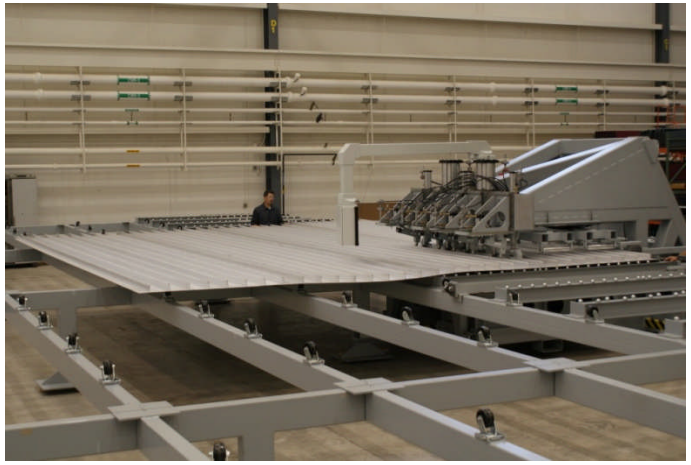
Conclusion

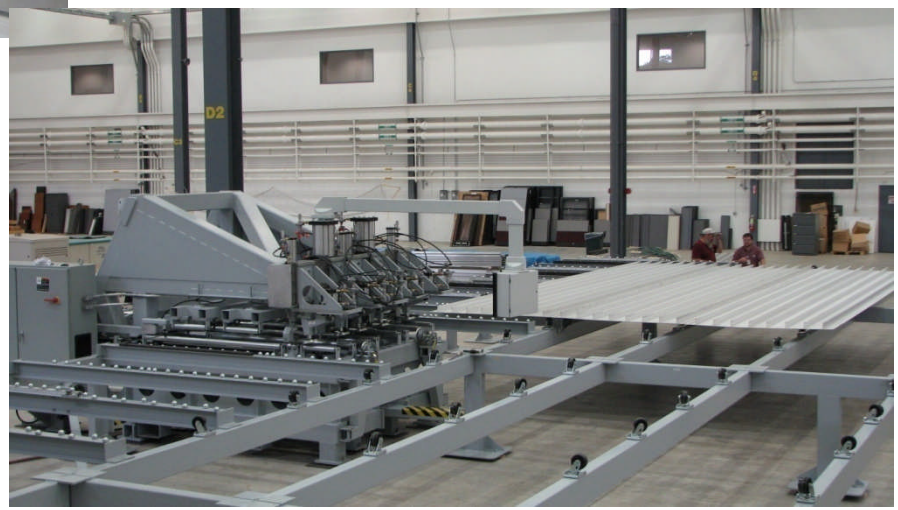
- **Low-cost FSW equipment presents opportunities**
  - **Efficient use of FSW on LCS ships and other Navy platforms**
  - **Demonstration of a new type of FSW equipment**
  - **Expand FSW to other DoD products requiring lightweight, stiffened panels**
  - **Pathfinder for other low-cost FSW concepts, such as FSW for thick section aluminum plate and friction stir processing**

Freedom-class LCS ship during sea trials, courtesy Lockheed Martin Team

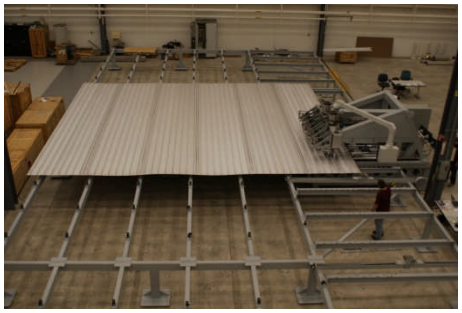
Miscellaneous Pictures







Miscellaneous Pictures



Miscellaneous Pictures