ITA - Titanium 2005
M777A1 Howitzer Cost Reduction Efforts
27 September 2005

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Program Manager
Joint Program Management Office
Joint Lightweight 155mm Howitzer
(JPM LW155)
Picatinny Arsenal, NJ 07806
Outline

- System Description
- M198/ LW155 Comparison
- Video

- EMD Manufacturing Background
- Implementation of Ti Castings
- Tube Development

- Lessons Learned
- Recommendations
- Summary
Prime Contractor & Developer,
Elevating Mass & Cradle Assembly
Barrow-in-Furness, England
Hattiesburg, MS

Joint Program Office
Picatinny Arsenal, NJ

80% US Content

Digital Fire Control
Burlington, VT

Titanium
Niles, OH

Wegmann USA
Elevating Gear
Lynchburg, VA

Upper Carriage
Whitehall, MI

Body Assembly
Hydro-Mill

Mission Computer
Software and Displays
Otto Company

Lower Carriage
Portland, OR

Cannon Assembly
Watervliet Arsenal
Watervliet, NY

Howmet Castings
an Alcoa business

Hydro-Mill Co.
A Triumph Group Company

OFC
St Louis, MO

Seiler Instrument

Joint Program Office
Picatinny Arsenal, NJ

GENERAL DYNAMICS
Strength on Your Side™

BAE SYSTEMS

RTI International Metals, Inc.

Wegmann USA
Elevating Gear
Lynchburg, VA

Upper Carriage
Whitehall, MI

Body Assembly
Hydro-Mill

Mission Computer
Software and Displays
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GENERAL DYNAMICS
Strength on Your Side™
Program Evolution

1996
LW155 Shoot-off

1997

2001
OT & Full Rate Production Dec.
OA, MS C and Low Rate Production
Final Developmental Testing
Extensive Developmental Testing
Continuous Live Fire Test & Feedback from Troops

2002
Rapid Force Projection Initiative (Early TAD)

2004
USMC IOC

2005
US Army TAD IOC

2006

2002
OT & Full Rate Production Dec.
OA, MS C and Low Rate Production
Final Developmental Testing
Extensive Developmental Testing
Continuous Live Fire Test & Feedback from Troops

1998
Textron Novation

1998

1997

1996
Contract Award & EMD Gun Design (8 Guns)
LW155 Shoot-off

The Future of Towed Cannon Artillery
# LW155 vs. M198

**LW155 is More Mobile, More Rapidly Deployable, More Survivable and More Accurate than the current heavy and aging M198**

<table>
<thead>
<tr>
<th>Feature</th>
<th>LW155</th>
<th>M198</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>9,800 lbs.</td>
<td>16,000 lbs</td>
<td>39%</td>
</tr>
<tr>
<td>Emplaces</td>
<td>2:10 min</td>
<td>6:35 min</td>
<td>304% ¹</td>
</tr>
<tr>
<td>Displaces</td>
<td>2:23 min</td>
<td>10:40 min</td>
<td>448% ¹ &amp; ²</td>
</tr>
<tr>
<td>Terrain Trafficable</td>
<td>83%</td>
<td>63%</td>
<td>32%</td>
</tr>
<tr>
<td>C-130 Load</td>
<td>2</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>TAD Ready</td>
<td>Yes</td>
<td>No</td>
<td>70% ²</td>
</tr>
<tr>
<td>Excalibur Ready</td>
<td>Yes</td>
<td>No</td>
<td>One Round Kill</td>
</tr>
</tbody>
</table>

¹ Contributes to 5 Times the Kills  
² Contributes to 70% Increase in Survivability
LW155 in Action

VIDEO
The Gun

- Upper Carriage Assembly
- Saddle Assembly
- Lower Carriage Assembly
- Final Integration

- Cradle Assembly
- Accumulator Assembly
- Buffer Assembly
- Buffer Yoke Assembly
- Balancer Assembly
- Scavenging Assembly
- Breech Assembly
- Trunnion Gearbox Assembly
- Damper Assembly
- Traverse Rack Assembly
- Spade Assembly
- Stabiliser Assembly
- Suspension and Wheel Assembly on Body
- Fully Assembled Elevation Mass
- Loading System Assembly
- Basic Ordnance
- Muzzle Brake Assembly
- Handwheel Assemblies
- Elevation Assembly
- Integrated Body and Saddle with Assembled Elevating Gear
- Complete Equipment
8 EMD guns manufactured by BAE Systems in the U.K.
- All Ti structures welded fabrications using manual TIG
- Plate work provided by RTI
- 3200 lbs of titanium per gun
- 6000 welding hours per gun
- Distortion issues with large Ti fabrications

EMD demonstrated the need for more robust manufacturing processes in order to meet quality, quantity and cost requirements for production.
Pilot Production Guns

- Added two additional guns to EMD phase
- Improved Welding processes (Assisted by EWI-ManTech)
- Implemented Supply Chain, vendors in U.S., U.K., Italy and Canada
- 23 Castings introduced for PP1 & PP2
  - Reduces welding hours by ~ 50%
  - Reduces Ti structures part count by 51%
  - Reduces manufacturing variability
  - Allows for ‘targeted’ strengthening of structures

Ti Castings a success, additional castings implemented for LRIP
Buffer Yoke

Balancer Eyes

Trunnion Caps

Axle Housings

Axle Caps

Upper Carriage Castings
Upper Carriage Castings (2)
Saddle Castings

Saddle Base

Saddle Arm L.H.

Balancer Posts

Saddle Arm R.H.
Lower Carriage Castings

Main Body

Front Legs

Rear Legs
Lower Carriage Castings

Trail Castings

Spade Blades

Stabilizers
# Part Count Reduction for Production

## Titanium Structure

<table>
<thead>
<tr>
<th>Part</th>
<th>Fabrication</th>
<th>Casting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cradle</td>
<td>324</td>
<td>172</td>
</tr>
<tr>
<td>Body</td>
<td>215</td>
<td>11</td>
</tr>
<tr>
<td>Saddle</td>
<td>116</td>
<td>5</td>
</tr>
<tr>
<td>Stabilizers</td>
<td>70</td>
<td>2</td>
</tr>
<tr>
<td>Spades</td>
<td>120</td>
<td>2</td>
</tr>
<tr>
<td>Trails</td>
<td>98</td>
<td>2</td>
</tr>
<tr>
<td>Elevating Yoke</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Buffer Yoke</td>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total Part Count**: 973 | 196

80% Part Count Reduction for Ti Structures
### Casting vs. Fabrication Weld Reduction

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Original # of welds</th>
<th>Production # of welds</th>
<th>Original weld length (ft)</th>
<th>Production weld length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Carriage</td>
<td>697</td>
<td>359</td>
<td>431</td>
<td>257</td>
</tr>
<tr>
<td>Saddle Assembly</td>
<td>430</td>
<td>68</td>
<td>229</td>
<td>33</td>
</tr>
<tr>
<td>Lower Carriage</td>
<td>1331</td>
<td>56</td>
<td>813</td>
<td>44</td>
</tr>
<tr>
<td>Total M777 Structures</td>
<td>2458</td>
<td>483</td>
<td>1473</td>
<td>334</td>
</tr>
</tbody>
</table>

- **80% Reduction in # of Welds**
- **77% Reduction in length of Welds**
Cradle Tube Development

Goal: Improve Quality and Decrease Cost of Cradle Tubes

Current Team: BAE, RTI, Nu-Tech, Dynamic Machine Works, PMF, CTC & J PMO

45 feet of tube per gun varying in lengths of 28-84”

Major Structural Component / Store Nitrogen for Recoil System

Significant Cost Driver
Cradle Tube Development

**Parallel Path:**

1. Work with Hot-Finish Tube (current method) vendors to improve quality (dimensional, finish, closer to near net final) & lower cost
   - RTI, Nu-Tech, Ti Engineers
2. Identify and evaluate alternative tube production processes
   - Dynamic Machine Works, PMF

CTC performed dimensional, metallographic, mechanical characterization of tubes supplied from vendors
- all vendors satisfied dimensions and tolerances
- all vendors exceeded AMS 4935G requirements

Competition amongst various vendors significantly reduced FRP cradle tube costs for LW155
- RTI Process Improvements Yielded Significant Cost Reduction
- RTI Awarded Full-Rate Production Contract
## Ti-6Al-4V Cradle Tube Materials & Processes

### Extruded Tubes

<table>
<thead>
<tr>
<th>Type of Tube</th>
<th>UTS (ksi)</th>
<th>YS (ksi)</th>
<th>Elong. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>β Extruded</td>
<td>139 + 1</td>
<td>124 + 1</td>
<td>13 + 0</td>
</tr>
<tr>
<td>α + β Extruded</td>
<td>152 + 1</td>
<td>144 + 1</td>
<td>15 + 1</td>
</tr>
<tr>
<td>Rotary Pierced</td>
<td>145 + 1</td>
<td>128 + 1</td>
<td>13 + 1</td>
</tr>
<tr>
<td>Flowformed</td>
<td>180 + 1</td>
<td>140 + 2</td>
<td>12 + 2</td>
</tr>
</tbody>
</table>

### ASTM B861 Requirement

<table>
<thead>
<tr>
<th>Type of Tube</th>
<th>UTS (ksi)</th>
<th>YS (ksi)</th>
<th>Elong. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>130</td>
<td>120</td>
<td>10</td>
</tr>
</tbody>
</table>
Lessons Learned

Manufacturing processes and capabilities need to play more significant role in EMD

- Design for affordability and ability to meet rate even if more costly in EMD by identifying where cost drivers are in processes to see if they can be designed out.

Designers need to develop better understanding of acceptance criteria for cast components to fully exploit process capabilities.

- Allowable surface flaws
- NDE requirements
Recommendations

- Development of non-aerospace casting spec needed (similar to D1.9 weld code).
  - Adaptable to component level requirements

- Effects of casting surface discontinuities on fatigue life needs better understanding.
  - Will allow ‘zoning’ of components to reduce rework, non-value added processing.

- Development of NDE (particularly x-ray) sampling criteria for smaller lot typical to ground vehicles.

- Reduce costs of SLA process. Will make cost of casting development more affordable.
Use of Titanium is the Only Means to Achieving LW155 Weight and Performance Requirements

Working with Titanium Vendors to Improve Manufacturing Processes has Improved the producibility, quality and cost of the LW155.

Government and Industry Need to Continue Cost Reductions Initiatives to ensure wider use of Titanium in future ground combat systems.