2.2 National Launch System 
Structures and Materials –
Jack O. Bunting, Martin Marietta 
Astronautics Group

Dr. Bunting stressed that Al-Li should be 
incorporated as a major structural material 
in space transportation vehicles. The 
National Launch System, as a joint NASA / 
Air Force program, provides an opportunity 
to realize the potential of Al-Li. Advanced 
structures can reduce weights by 5-40% as 
well as relax propulsion system performance 
specifications and reduce requirements for 
labor and materials. The effect on costs will 
be substantial. For example, a redesigned 
external tank fabricated from Al-Li would 
weigh 8 klb less than existing ET’s and, as a 
result, reduce effective launch costs by $800 
per pound of payload.

Advanced assembly and process control 
technologies also offer the potential for 
greatly reduced labor during the 
manufacturing and inspection processes. 
Current practices are very labor-intensive 
and, as a result, labor costs far outweigh 
material costs for operational space 
transportation systems.

The technological readiness of new 
structural materials depends on their 
commercial availability, producibility and 
materials properties. Martin Marietta is 
vigorously pursuing the development of its 
Weldalite™ 049 Al-Li alloys in each of these 
areas. Al-Li alloys are now commercially 
available, they have been used in high quality 
welds, and they perform as expected in 
terms of yield strength and ultimate 
strength. Martin Marietta tests have 
demonstrated satisfactory welds using a 
variety of techniques in test articles 
composed entirely of Al-Li and in joining 
Al-Li to aluminum. Preliminary 
demonstrations of producibility based on the 
design of the Space Shuttle external tank 
have also been successful, and more complex 
tests are continuing.

Martin Marietta is also preparing to test an 
automated work cell concept that it has 
developed using discrete event simulation. 
One of the goals of this effort is to develop a 
manufacturing process that features 
continuous inspection of welded joints as 
they are created and thereby eliminate the 
time consuming practice of inspecting welds 
after the fact as a separate step of the 
fabrication process. Martin Marietta is 
currently procuring tooling for initial 
demonstrations.
Baseline Vehicles

1.5 STAGE
TITAN IV 86 ft SHROUD NEW ADAPTER UPPER STAGE OPTION
SUSTAINER STMEs

COMMON CORE
FORWARD INTERSTAGE
FORWARD SKIRT TANKAGE / INTERTANK
- STD SIZE / MATERIALS
- BEEFUP FOR 1.5 STG APPLICATION
AVIONICS THRUST STRUCTURE / PROPULSION
- INFLIGHT SEP. SYSTEMS STMEs STRUCTURE / PROPULSION FOR 2 CENTER STMEs AFT SKIRT - VEHICLE HOLDDOWN

HLLV
TITAN IV 86 ft SHROUD OPTIONAL SHROUD FOR STS PAYLOADS (40' STRONG-BACK) CTV ASRM

Existing Launch Vehicles

Structures Technology
- Aluminum Alloys 2219, 2014
- Fabrication Techniques
  - Machine, Stretch Form
  - Chem Mill to Tight Tolerances
- Manual Inspection

Assembly & Process Control Technology
- Manual Material Handling
- Manual Part Set-Up
- Manual Part Weld Prep
- Manual Part Fit-Up
- Point Design Weld Processes
- Manual Inspection

Advanced Technology

Structures Technology
- Reduce Weight (5 - 40%)
- Reduce Direct Labor/Material
- Reduce Support Labor
- Reduce Propulsion Requirements

Assembly & Process Control Technology
- Reduce Direct Assembly Labor (30%)
- Reduce Major Weld Labor (34%)
- Reduce Inspection Labor (33%)
Delta Payload vs Stretch for Weldalite™ 049 Substitution

- LH₂ Tank Stretch + Weldalite™ 049 Use
- LH₂ Tank Stretch
- Weldalite™ 049 Resizing
- NLS 1.5 Stage LH₂ Tank Baseline

Weldalite™ 049 and The External Tank (ET)

- Redesign of the ET Using Weldalite™ 049 Can Result in A Weight Savings of Approximately 8000 lb
- This Equates to a Savings of Cost to Orbit of about $800/lb
Al-Li Alloys

Success Criteria

- Demonstrated Production Capability
- Demonstrated Cost Advantage through Higher Strength
- Adequate Fracture Toughness
- Adequate Stress Corrosion Resistance
- Demonstrated Manufacturability

Technology Readiness of Al-Li Alloys

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Present Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Availability</td>
<td>Alloys Are Currently Available</td>
</tr>
<tr>
<td>Producibility</td>
<td></td>
</tr>
<tr>
<td>- Forming</td>
<td>Full Scale External Tank Gores and Extruded Chords Have Been Produced. All Meet Design Tolerances</td>
</tr>
<tr>
<td>- Chem-milling</td>
<td>Chem-milled Gores Meet Design Requirements</td>
</tr>
<tr>
<td>- Machining</td>
<td>Extruded Chords Have Been Machined and Meet Design Requirements</td>
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</tbody>
</table>
Technology Readiness of Al-Li Alloys (Concl.)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Present Status</th>
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<tbody>
<tr>
<td>Welding</td>
<td>High Quality Welds Have Been Produced by All Conventional Processes Including VPPA. Backside Shielding Concepts Have Been Demonstrated</td>
</tr>
<tr>
<td>Design Allowables</td>
<td>All Product Forms of Weldalite™ 049 Have Been Shown to Meet the Specified Yield Strength of 85 ksl and the 90 ksl Ultimate Strength Goal. Reynolds Will Begin the &quot;S&quot; Basis Allowables Program in Late 1991</td>
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Advanced Cryotank Program - ADP 3106
Weldalite™ 049 Development

- Concurrent Engineering Team Formed
  - Martin Marietta
  - Reynolds Metals Co.
  - Universities
  - Government Agencies
- Laboratory Production at RMC
- Lab Scale Properties Exceed Other Tankage Alloys

1988
- Weldalite™ 049-T6
  - 2090-T61
  - 2219-T97

1989
- Full Scale Production at RMC
  - 13,000 lb Ingots Produced
  - Plate and Sheet Material Characterized
  - Typical Properties
    - Ftu = 100 ksi
    - Fty = 90 ksi
- Small Scale Net Shaped Products Manufactured
  - Hook Forgings
  - Domes (18" Dia)
  - Extrusions
  - Weldability Demonstrated

Weld Properties
- STGTA
- STGTA-VP
- VPPA
- VPPA (2219)
Advanced Cryotank Program - ADP 3106
Weldalite™ 049 Development

**1990**
- Large Products Produced
  - Extruded External Tank (ET) Chord
  - ET Gore Panels
  - Domes (42" Dia)
  - Extruded Barrel Panels (18" Width)
  - Roll Forged Ring (34" Dia)

**42" Dome Properties**

**1991**
- In Progress:
  - Integrally Stiffened Extruded Tube Producing 105" Wide x 360" Length Barrel Panel
  - 120" Dia Dome Spin Forming
  - Weld Process Optimization

**STATUS:**
- Alloy - Lab to Production In 3 Years
- Net Shapes Demonstrated
- Exceeded Mechanical Property Goals

**1992-93**
- Components for 14' Dia Tank Manufactured
- Fabricate Tank
- Test Tank at Cryogenic Temperatures

![Diagram showing cryotank components and properties](image-url)