Recent Advances in Near-Net-Shape Fabrication of Al-Li Alloy 2195 for Launch Vehicles

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Outline

- Background on Al-Li alloy and Near-Net-Shape Fabrication Technologies for the Launch Vehicle industry
- Ares I Roll Forged Adapter Rings
- Exploration Technology Development Program Spun Formed Domes
- Future Opportunities for 2195 Near-Net-Shape Components
- Remaining Challenges

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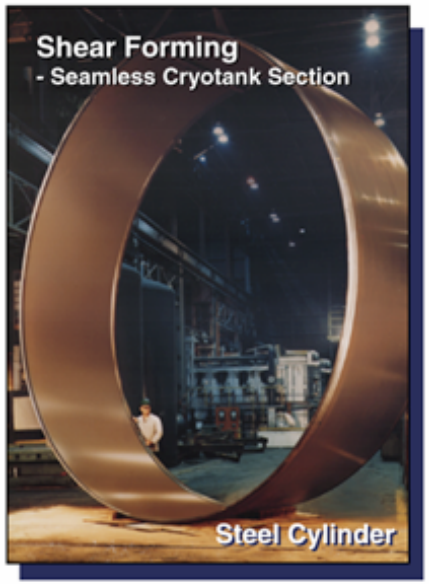
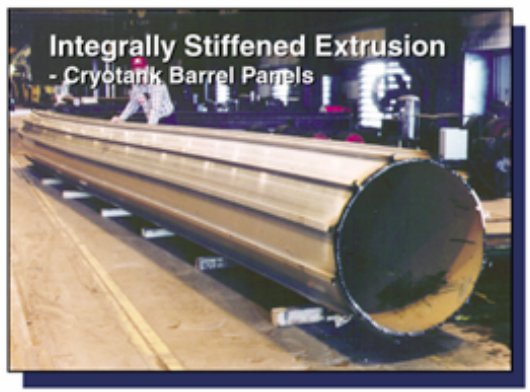
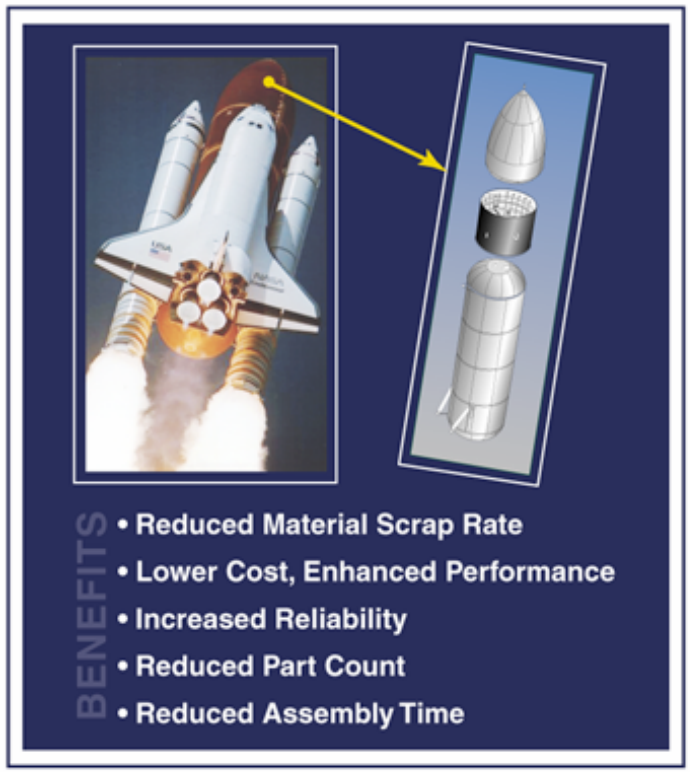
Near-Net-Shape Manufacturing of Al & Al-Li Alloys For Launch Vehicle Structures







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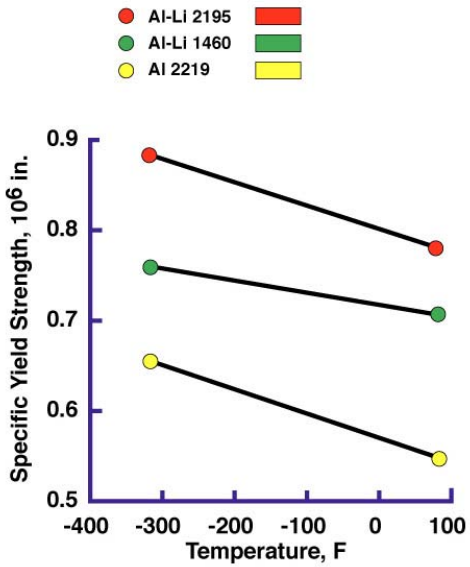
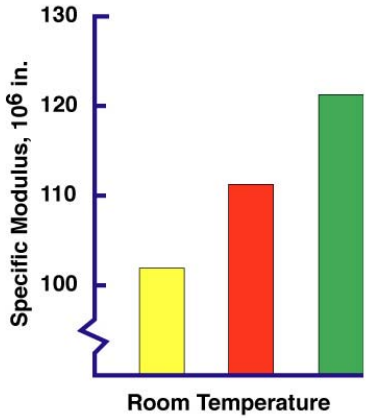
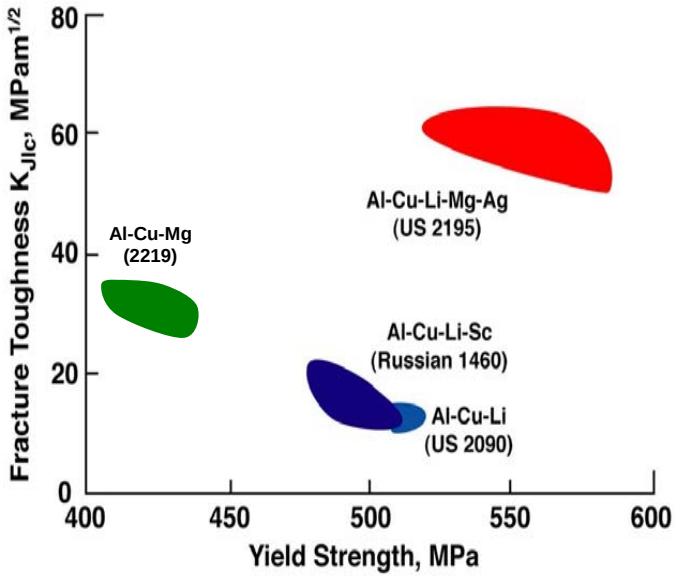
Advanced Aluminum Alloys Technologies for Space Transportation Systems







Benefits of Al-Li Alloys

- Lower Density
- Higher Strength
- Higher Modulus
- Good Cryogenic Toughness
- Good Formability & Weldability

Current Applications

- Space Shuttle External Tank and Intertank Structures
- F-16 Bulkheads
- Airbus A380 primary structure

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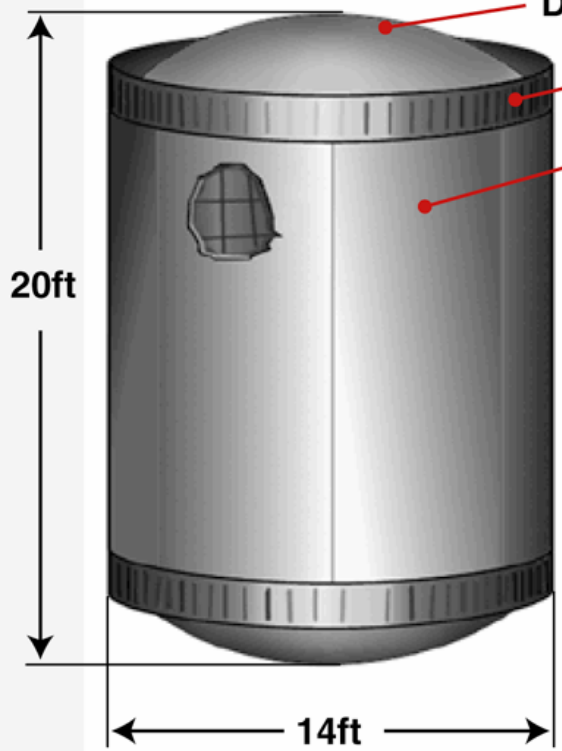
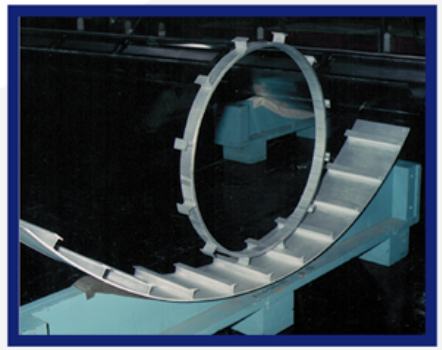
Cryogenic Tank Technology Program

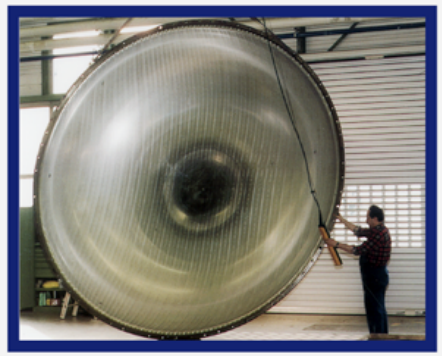


- Joint NASA LaRC-MSFC-Lockheed Martin
- Applies Al-Li Near Net Forming Methods Developed Through LaRC Programs
- Longitudinal & Circumferential Friction Stirwelds at MSFC
- Concept Demonstration Tank
- Constructed from Al-Li alloy 2195

Vendors

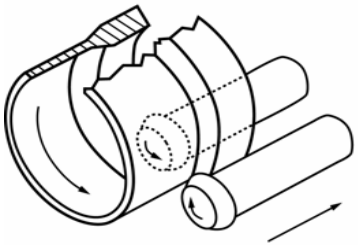
- McCook Metals Co.- 2195 Al-Li Alloy
- Zeppelin - Spun Formed Domes
- Wyman Gordon - Extruded Barrel Section Panels
- Ladish Corp. - Roll Forged Adapter Rings





PROCESS OPTIMIZATION FOR THIN-WALLED 2195 ALUMINUM SHEAR FORMED CYLINDERS

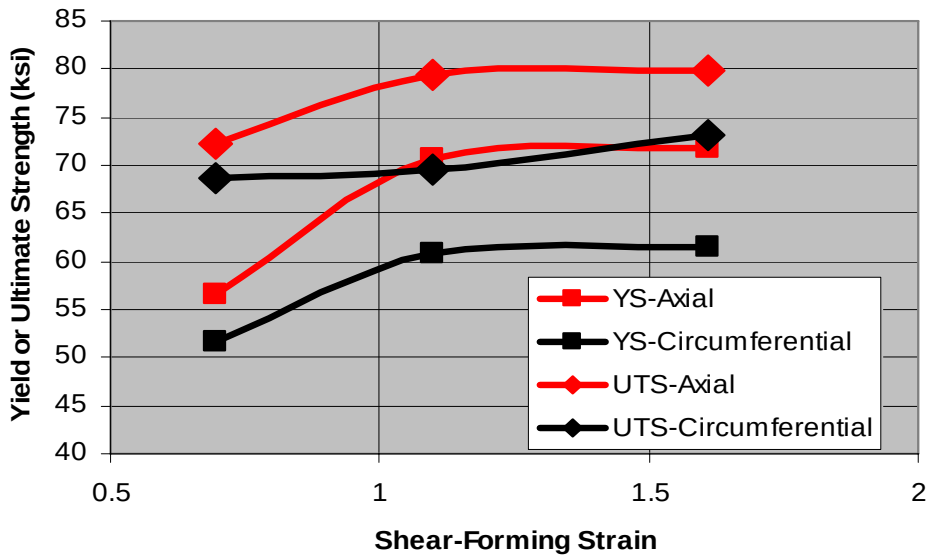
Shear Forming Process



2195 Shear Formed Cylinder
(14' Diameter; 0.18" Wall Thickness)

Process Potential
- Seamless cylinders up to 22 foot diameter
- Reduce/eliminate longitudinal joints/welds

Tensile Properties of 14' Diameter 2195-T8 Shear Formed Cylinder

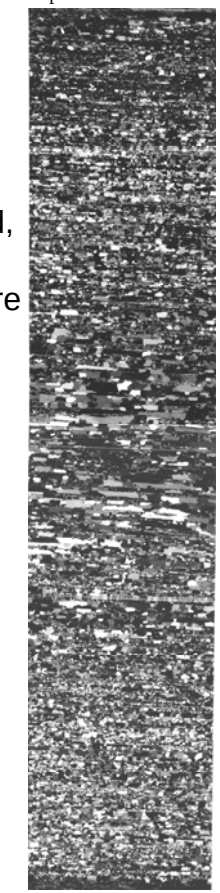


Through-Thickness Microstructures of 14' Diameter Al-Li 2195 Shear Formed Cylinders

2195 SFC I
t_f=0.15 inches

Process parameter optimization yields refined, symmetrical microstructure

2195 SFC II
t_f=0.18 inches



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Space Shuttle Super Lightweight External Tank

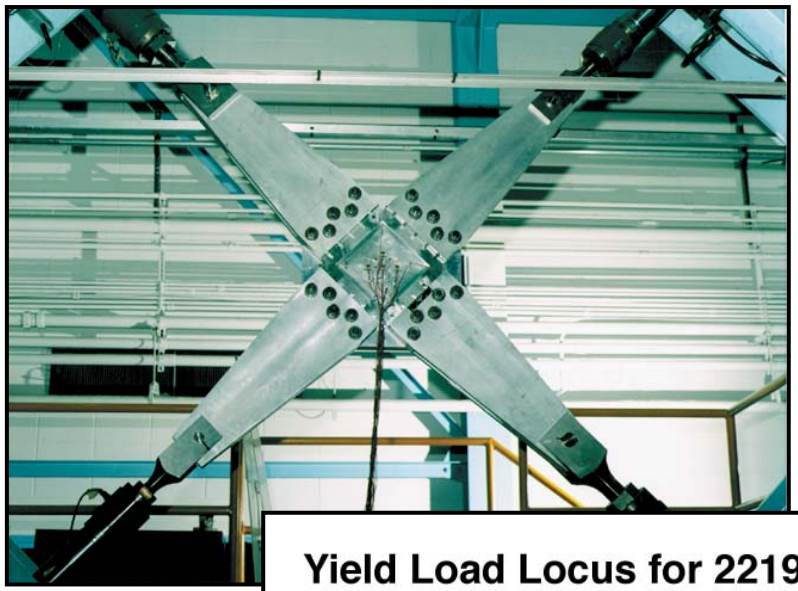
- **Space Shuttle system redesigned to support space station launch requirement of 51.6º angle of inclination**

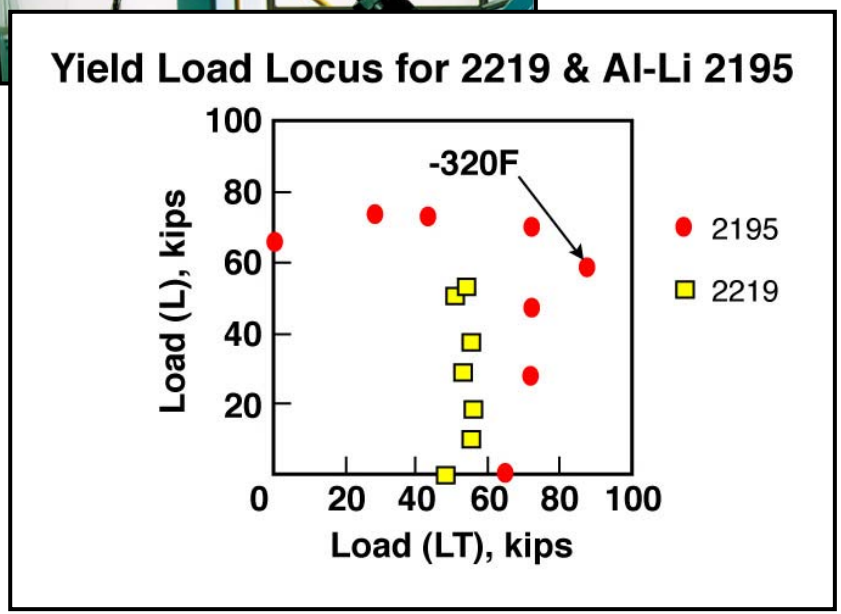
- **SLWT program requirement was an 8,000 lb. system weight reduction**
  - **System redesigned: T-stiffened → orthogrid**
  - **Material Replacement: Al 2219 → Al-Li 2195**

- **Program initiated in 1994; First SLWT flight was STS-91, June 1998**

Super Lightweight Tank Program
Materials Testing and Characterization Program

Biaxial Test Stand





Alloy Development
- Composition
- Processing
- Aging
- Plate, extrusions, forgings

Mechanical Property Evaluation
- Tensile/Compression
- Precision Modulus
- Fracture Toughness
- Biaxial Tension
- Amsler Shear

Metallurgical Characterization
- Metallography
- Chemical Analysis
- Microhardness
- Fractography
- Differential Scanning Calorimetry

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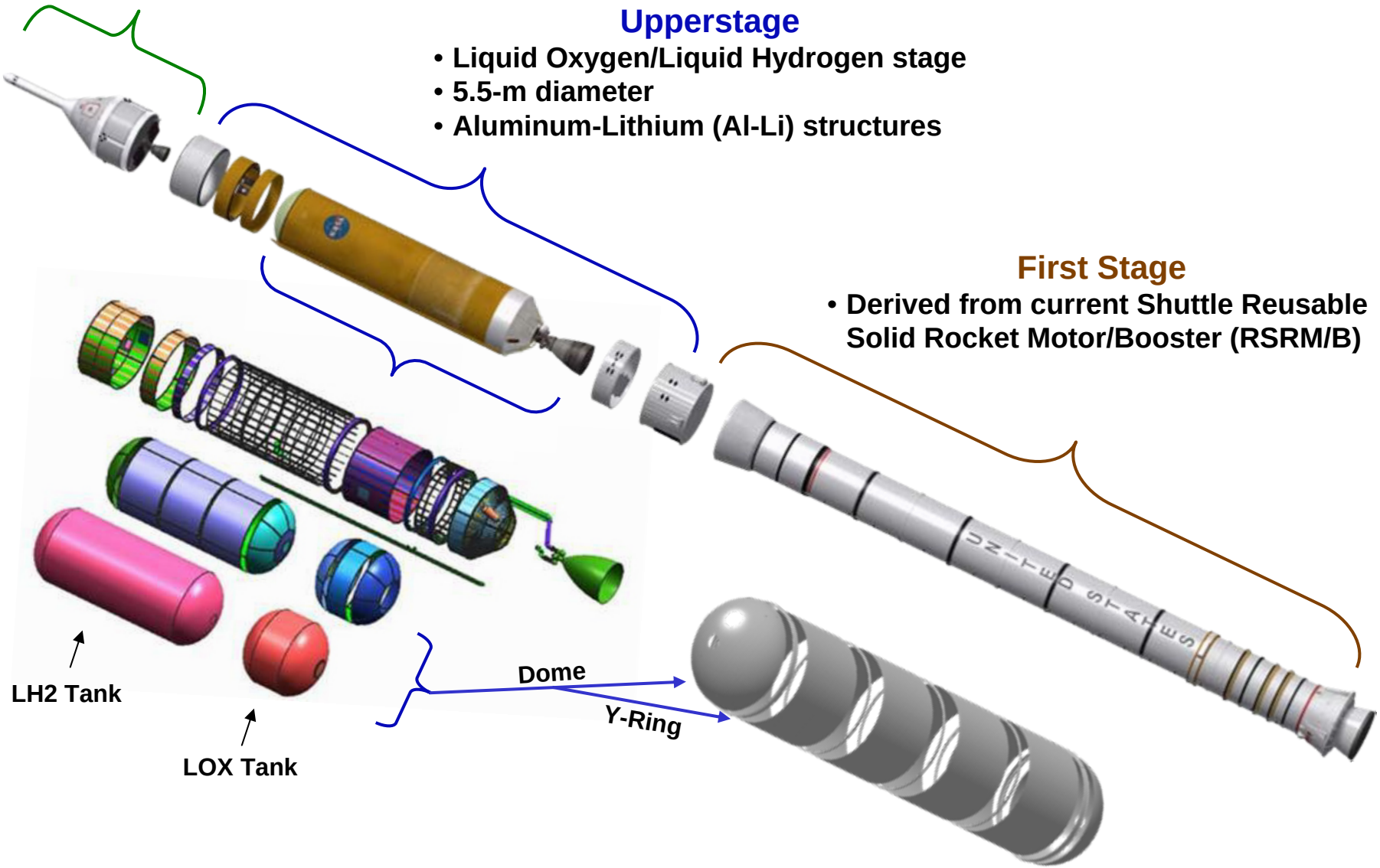
Ares I Configuration
Crew Launch Vehicle (CLV)

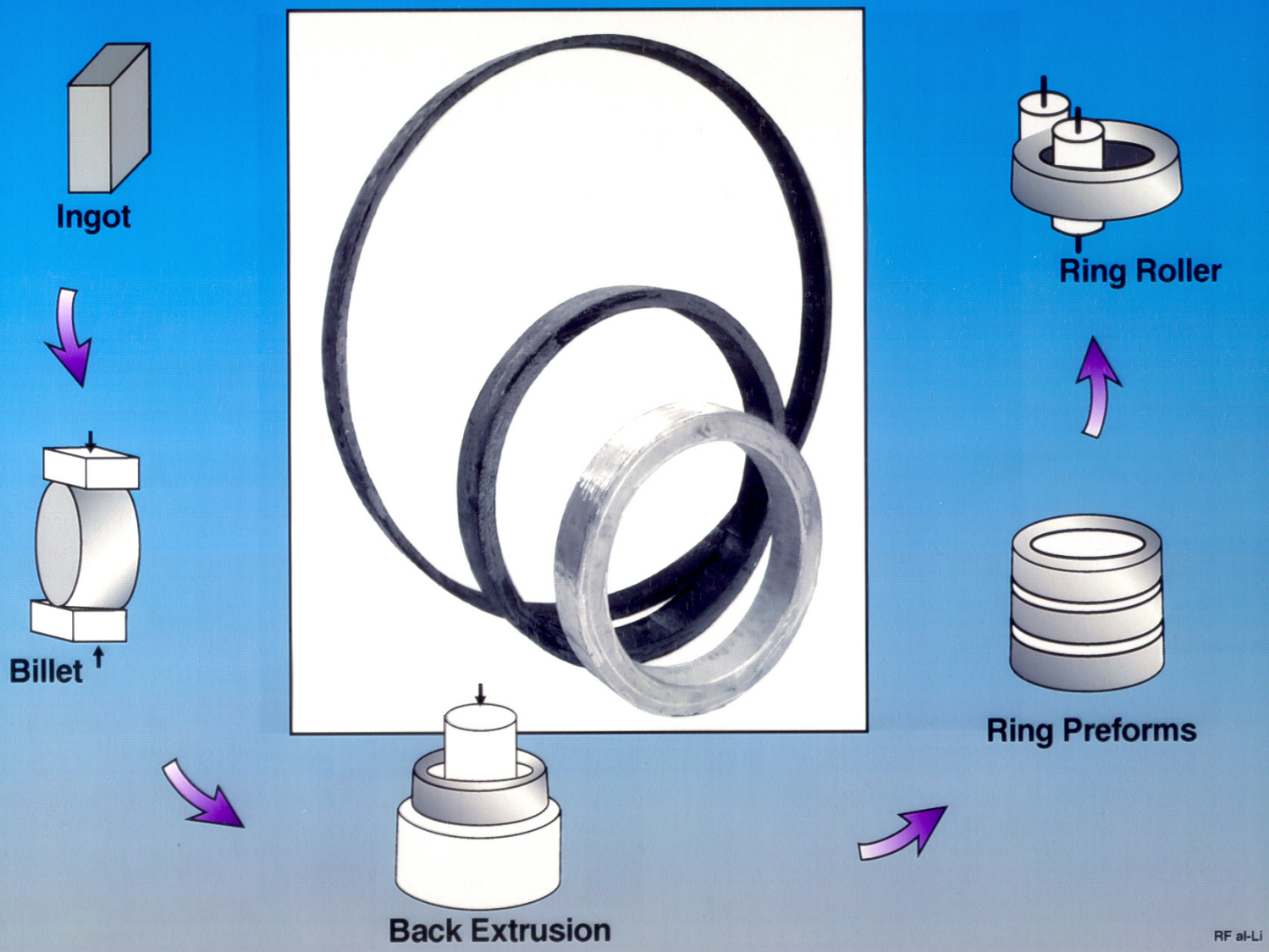
Orion
- Crew Exploration Vehicle (CEV)

Upperstage
- Liquid Oxygen/Liquid Hydrogen stage
- 5.5-m diameter
- Aluminum-Lithium (Al-Li) structures

First Stage
- Derived from current Shuttle Reusable Solid Rocket Motor/Booster (RSRM/B)



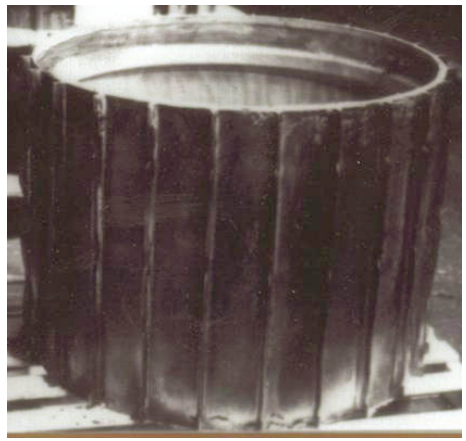
Roll Forged Al-Li 2195 Process Development Rings

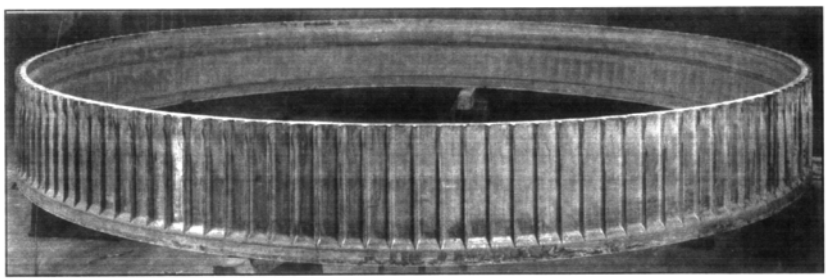


Near-Net-Shape Manufacturing of Al-Li Alloy 2195 for Launch Vehicles

Target Properties					
Temper	Thickness (in)	Orient.	UTS, Min. (ksi)	YS, Min. (ksi)	% el, Min.
T8A3	0.5 to 2.0 in.	Circ. / Axial	78	73	5
		Radial	70	63	2

CLV Upper Stage Manufacturing Requirements Document





Demonstrated Properties					
Temper / Orientation	Temp.	Thickness (in)	UTS (ksi)	YS (ksi)	% el
T8 / Axial	RT	1.0 in.	83.0	75.0	10.1
		2.0 in.	82.8	75.6	9.1
	LN2	1.0 in.	98.4	88.9	7.8
		2.0 in.	95.6	84.3	10.6

Average of Multiple Roll Forgings

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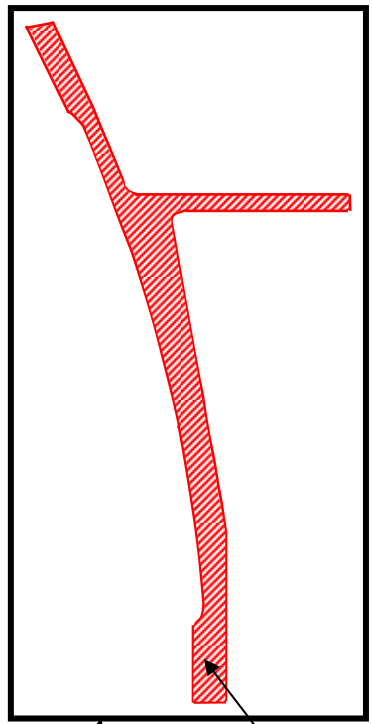
ARES I Cryogenic Tank Single-Piece Y-ring Adapter Manufacturing Plan

Al-Li 2195 ingot processing to rough pre-form

Roll forge to target diameter
Rectangular cross section

Contour machine
Post-fabrication processing

Final Machine



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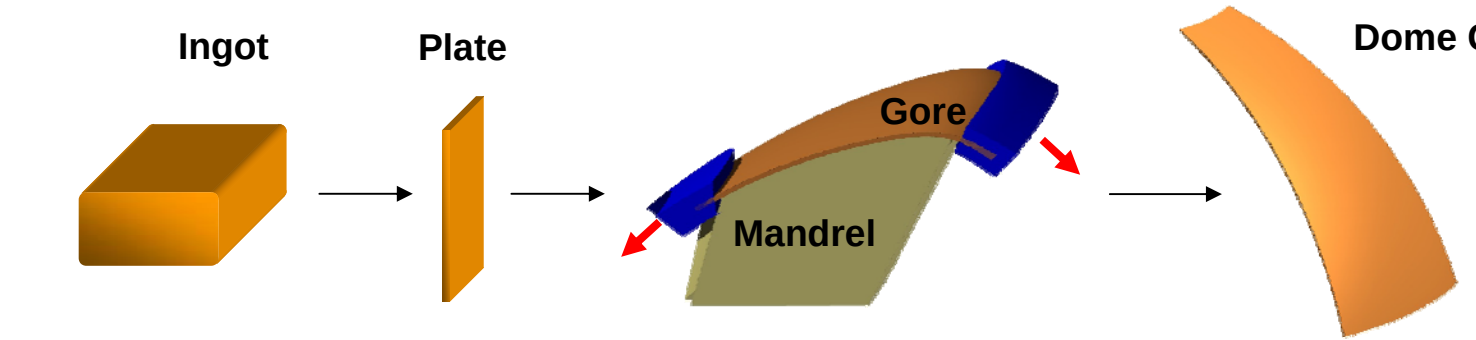
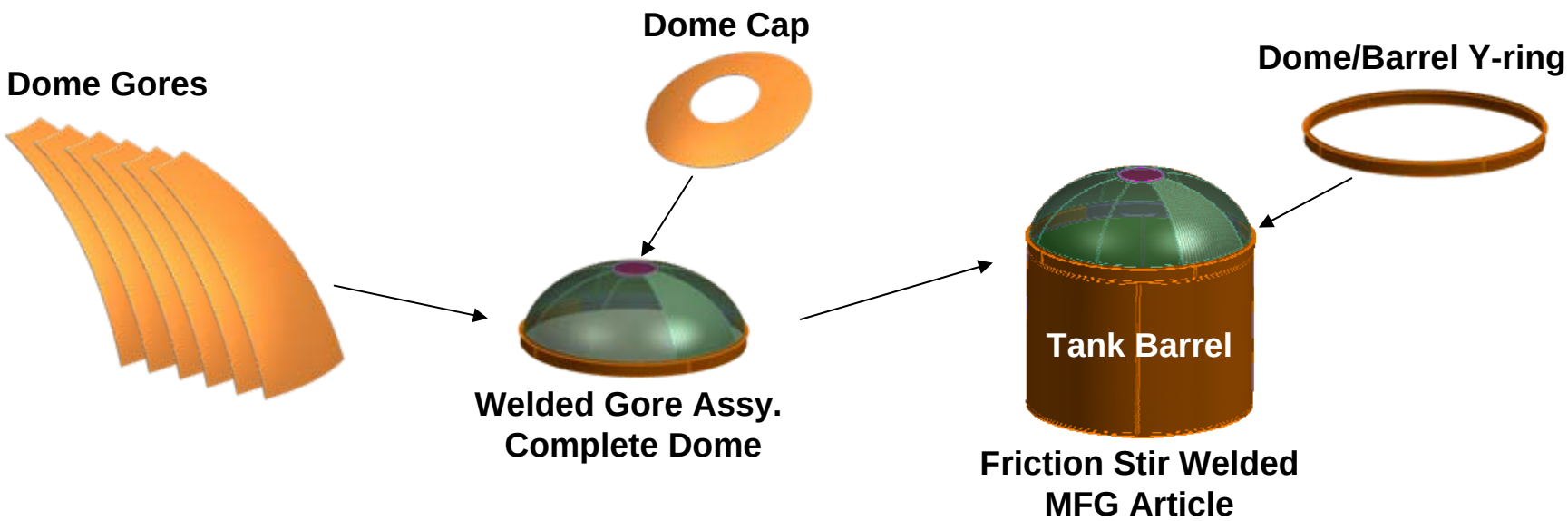
Cryogenic Tank Dome Manufacturing by Gore Assembly

Multi-piece; Welded Construction





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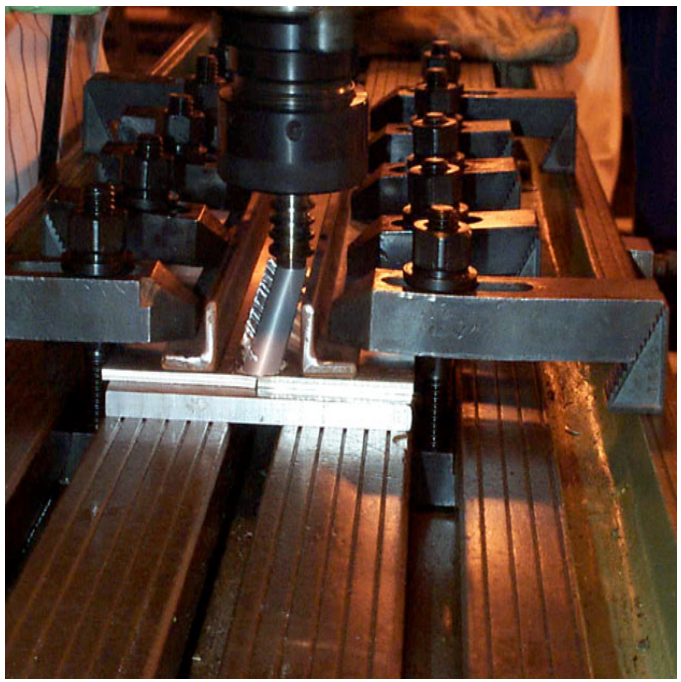
ARES I Cryogenic Tank Single-Piece Dome Manufacturing Plan

Friction Stir Welded Al-Li 2195 Plate → **Spin Forming** → **Post-fabrication Processing**

2195 commercial plate limits spin forming blank size

FSW multi-piece blank

FSW is mature technology for 2195



2195 spun formed dome
Sub-scale
FSW blank

Al-Li Alloy 2195
14-foot diameter
Single piece blank

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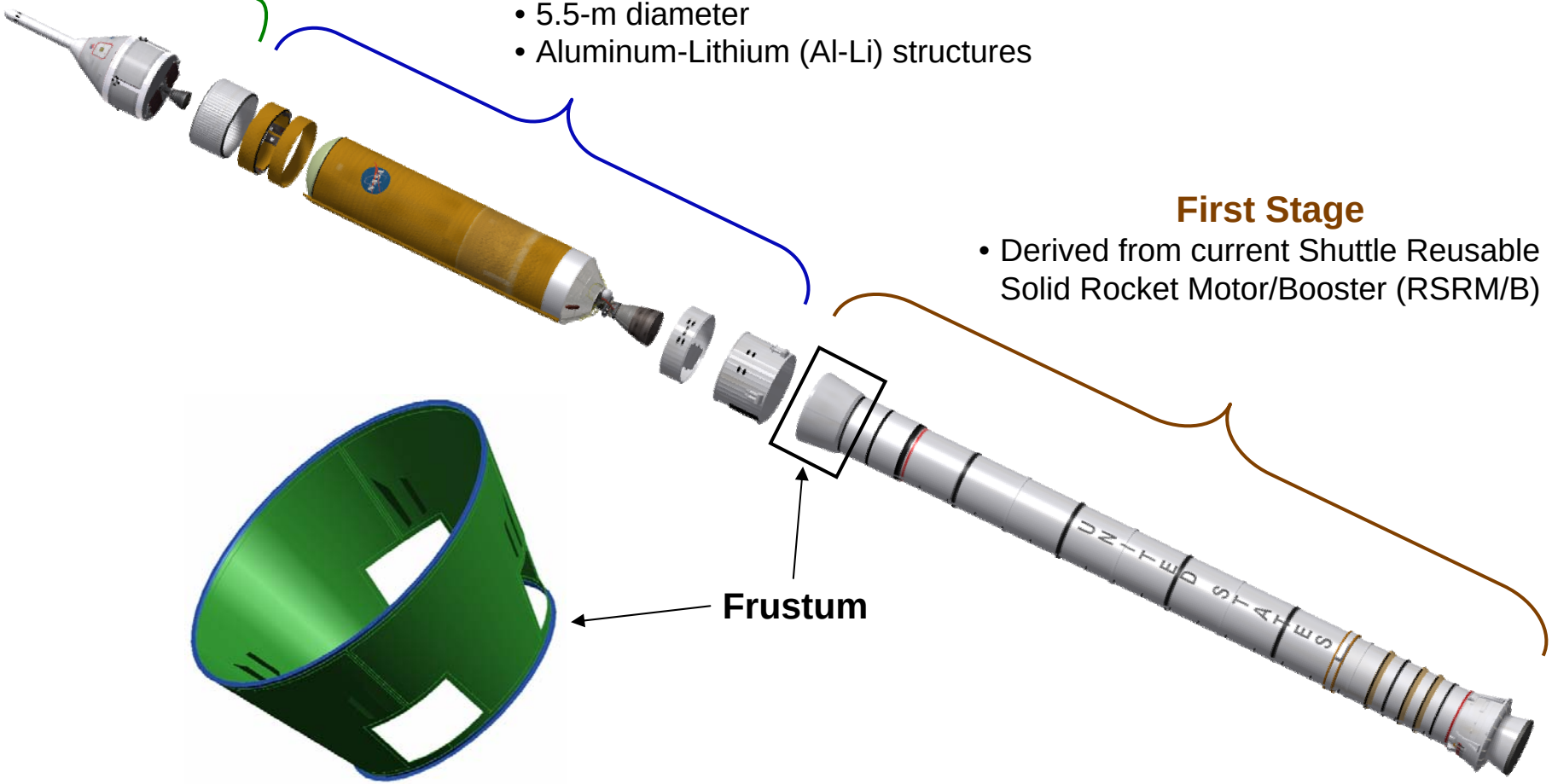
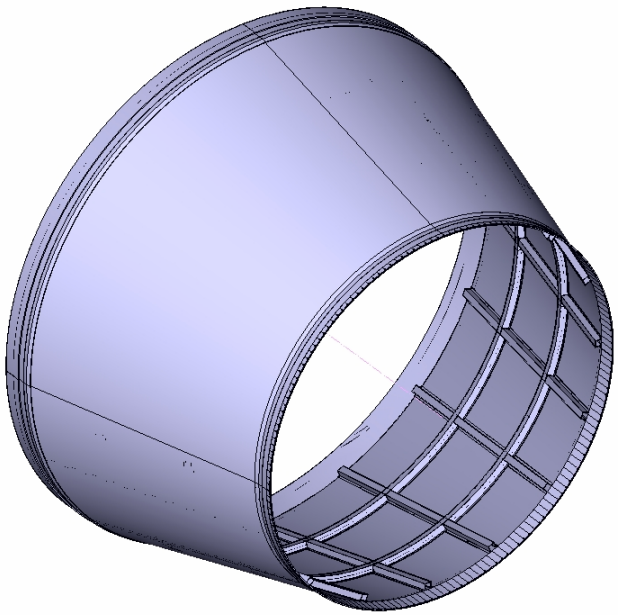


Launch Vehicle Frustum Concept and Ladish Produced Forward Exit Cone

Typical Frustum Structure



Forward Exit Cone

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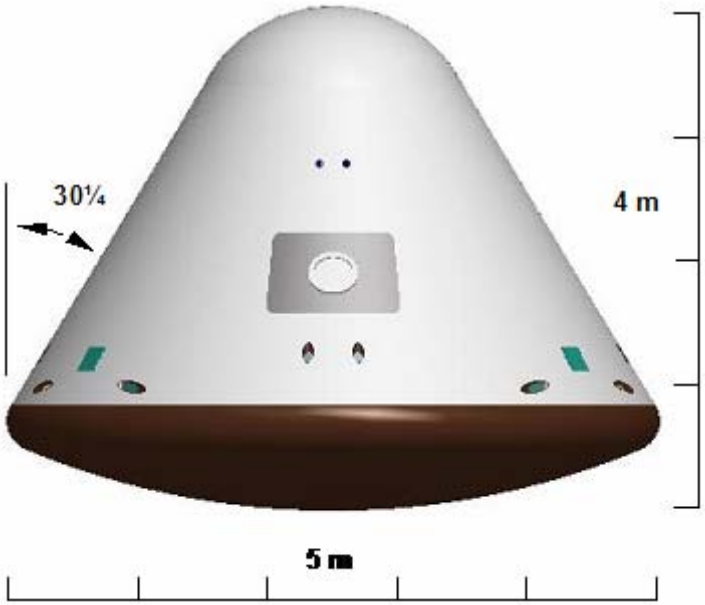
Potential Applications to Orion
Crew Exploration Vehicle (CEV)



- Rings
- Cylinders
- Conical Shapes
- Tanks

Recent Advances in Near-Net-Shape Fabrication of Al-Li Alloy 2195 for Launch Vehicles

Remaining Challenges

Recent applications in launch vehicles use 2195 processed to Super Lightweight Tank specifications. Potential benefits exist by tailoring heat treatment and other processing parameters to the application.

Assess the potential benefits and advocate application of Al-Li near-net-shape technologies for other launch vehicle structural components.

Work with manufacturing and material producers to optimize Al-Li ingot shape and size for enhanced near-net-shape processing.

Examine time dependent properties of 2195 critical for reusable applications.

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