BUILT-UP Al-Li STRUCTURES FOR CRYOGENIC TANK AND DRY BAY APPLICATIONS

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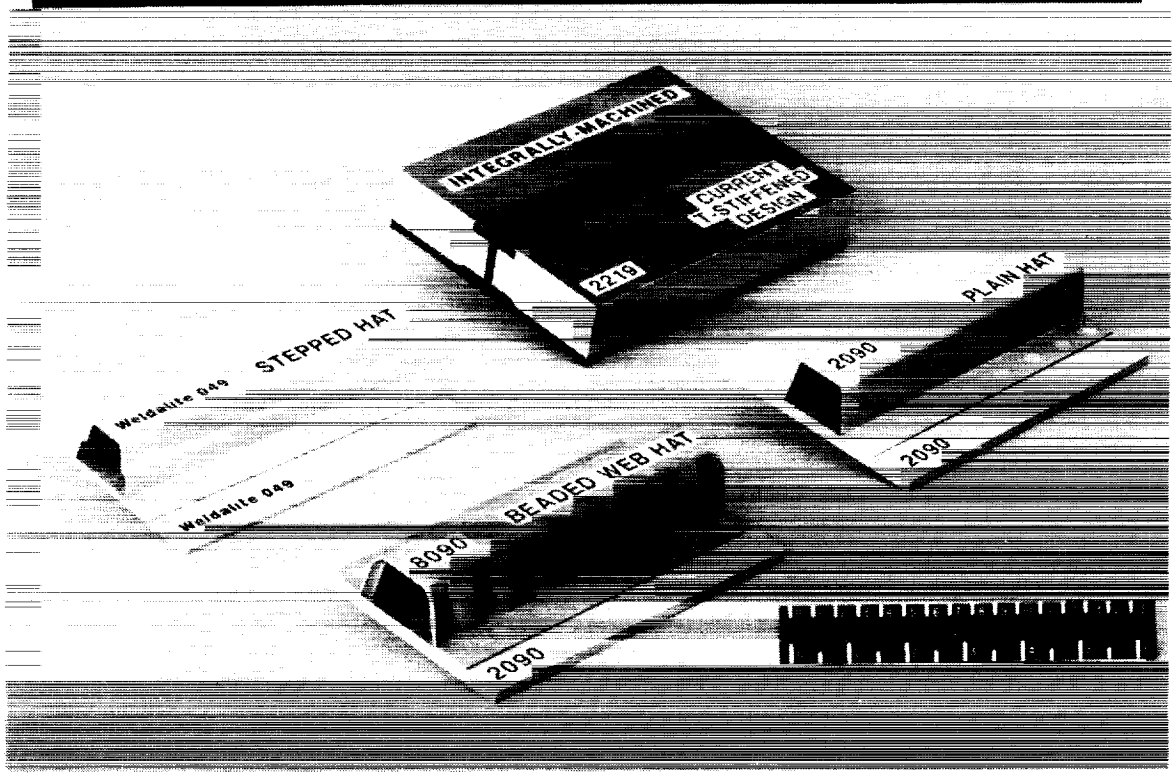
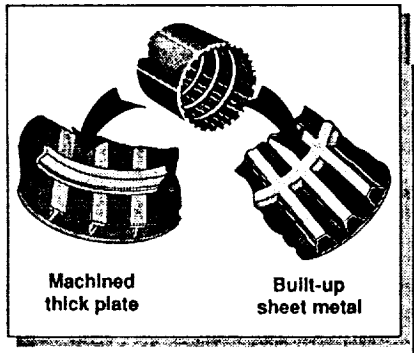
SPF TECHNOLOGY FOR Al-Li BUILT-UP STRUCTURES



ADVANCED LAUNCH SYSTEM

Structures, Materials & Manufacturing

Built-up structures for ALDP #3104



Responsible Org: NASA/LaRC
Execution: LaRC/Rockwell/GD
Funding ($M):

	4.9	0.4	0.1	1.5	2.0		8.9
FY	Prior	90	91	92	93	ΔTC	Total
Built-up panel concepts defined	(1) complete						
SPF and RSW parameters established			(2)				
Test stiffener and column buckling panels					(3)		
Materials characterization and properties					(4)		
Fab and test subscale barrel section					(6)		

Objectives:
- Demonstrate the cost benefits of built-up cryotank & dry bay structures
  - Conventional Al alloys
  - Low density Al-Li alloys
  - Evaluate alternative low-cost stiffener and joining concepts

Payoffs:
- Lower weight/lower system costs
- Significant reduction in tank costs
  - Reduced scrap rate/lower material costs
  - Reduction in major machining costs
  - Avoid thick plate issues

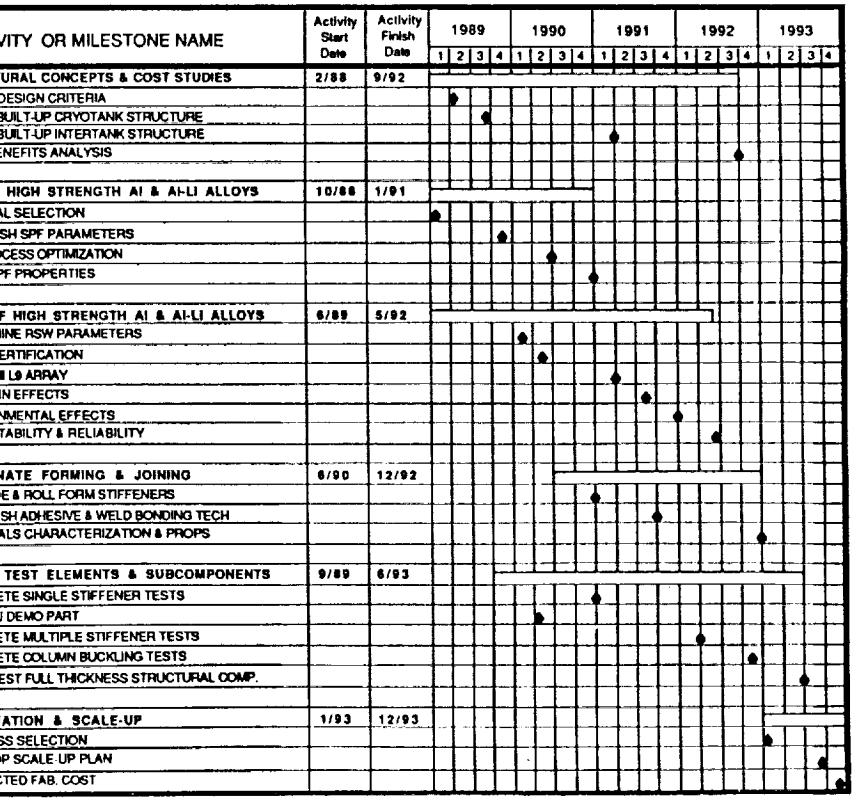
TASK #3104 BUILT-UP STRUCTURE FOR CRYOTANKS

Program Participants

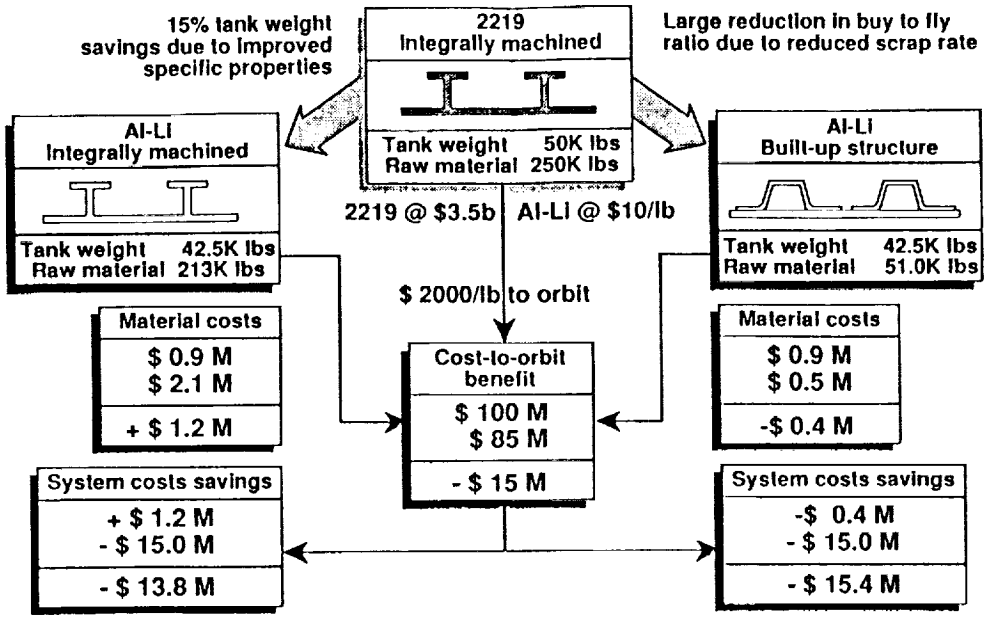
Organization	Key activity
• NASA -LaRC	• SPF/RSW • Alternate forming & joining methods
- Martin Marietta	- SPF of chemistry modified Weldalite™
- Reynolds	- Weldalite stiffener extrusions
• Rockwell	• SPF of Al & Al-Li alloys
• General Dynamics	• RSW of Al & Al-Li alloys

ADP TASK #3104 BUILT-UP ALUMINUM CRYOTANKS

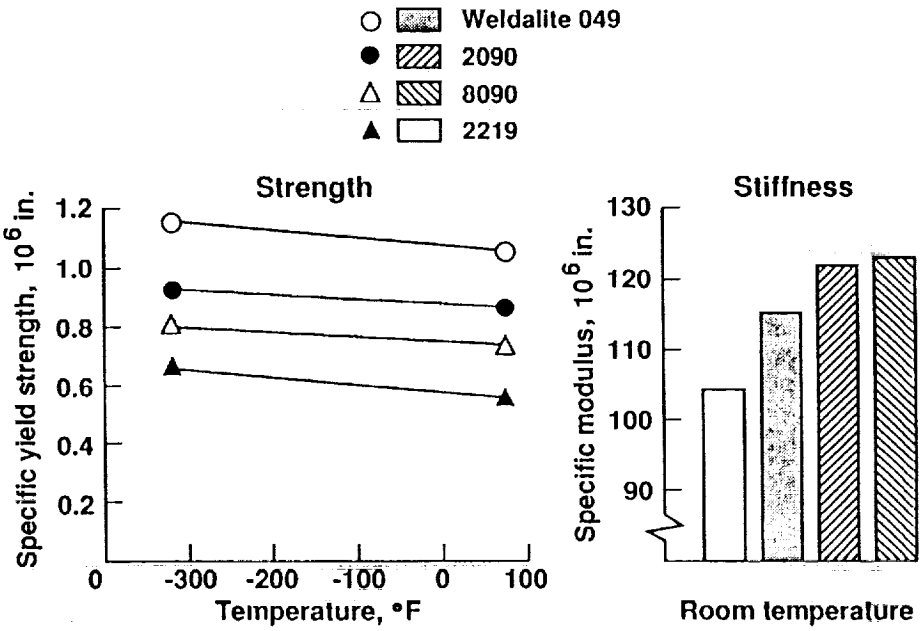
ACTIVITY OR MILESTONE NAME	Activity Start Date	Activity Finish Date
1.0 STRUCTURAL CONCEPTS & COST STUDIES	2/88	9/92
1.1 DEFINE DESIGN CRITERIA		
1.2 DEFINE BUILT-UP CRYOTANK STRUCTURE		
1.3 DEFINE BUILT-UP INTERTANK STRUCTURE		
1.4 COST BENEFITS ANALYSIS		
2.0 SPF OF HIGH STRENGTH Al & Al-Li ALLOYS	10/88	1/91
2.1 MATERIAL SELECTION		
2.2 ESTABLISH SPF PARAMETERS		
2.3 SPF PROCESS OPTIMIZATION		
2.4 POST-SPF PROPERTIES		
3.0 RSW OF HIGH STRENGTH Al & Al-Li ALLOYS	6/89	5/92
3.1 DETERMINE RSW PARAMETERS		
3.2 WELD CERTIFICATION		
3.3 TAGUCHI L9 ARRAY		
3.4 RSW SKIN EFFECTS		
3.5 ENVIRONMENTAL EFFECTS		
3.6 INSPECTABILITY & RELIABILITY		
4.0 ALTERNATE FORMING & JOINING	6/90	12/92
4.1 EXTRUDE & ROLL FORM STIFFENERS		
4.2 ESTABLISH ADHESIVE & WELD BONDING TECH		
4.3 MATERIALS CHARACTERIZATION & PROPS		
5.0 FAB & TEST ELEMENTS & SUBCOMPONENTS	9/89	6/93
5.1 COMPLETE SINGLE STIFFENER TESTS		
5.2 FAB Al-Li DEMO PART		
5.3 COMPLETE MULTIPLE STIFFENER TESTS		
5.4 COMPLETE COLUMN BUCKLING TESTS		
5.5 FAB & TEST FULL THICKNESS STRUCTURAL COMP.		
6.0 AUTOMATION & SCALE-UP	1/93	12/93
6.1 PROCESS SELECTION		
6.2 DEVELOP SCALE UP PLAN		
6.3 PROJECTED FAB. COST		



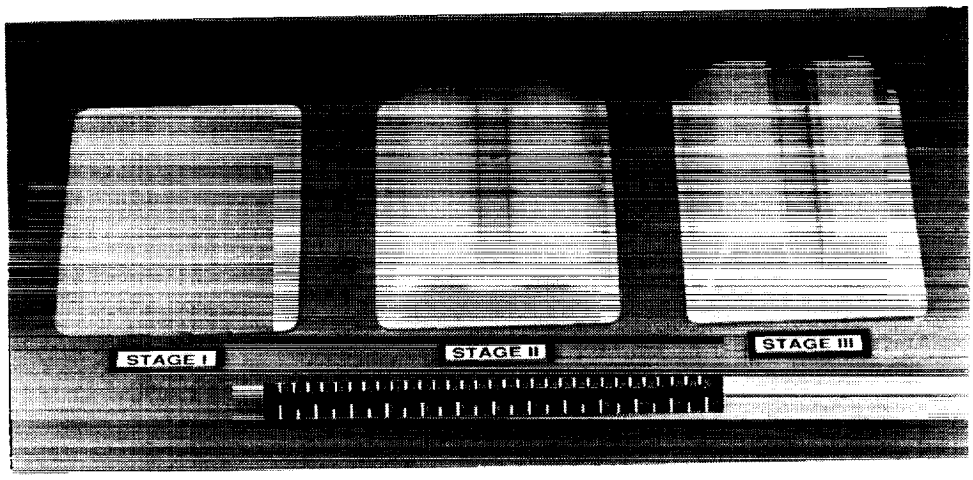
BENEFITS OF USING AL-LI ALLOYS FOR CRYOGENIC TANKS



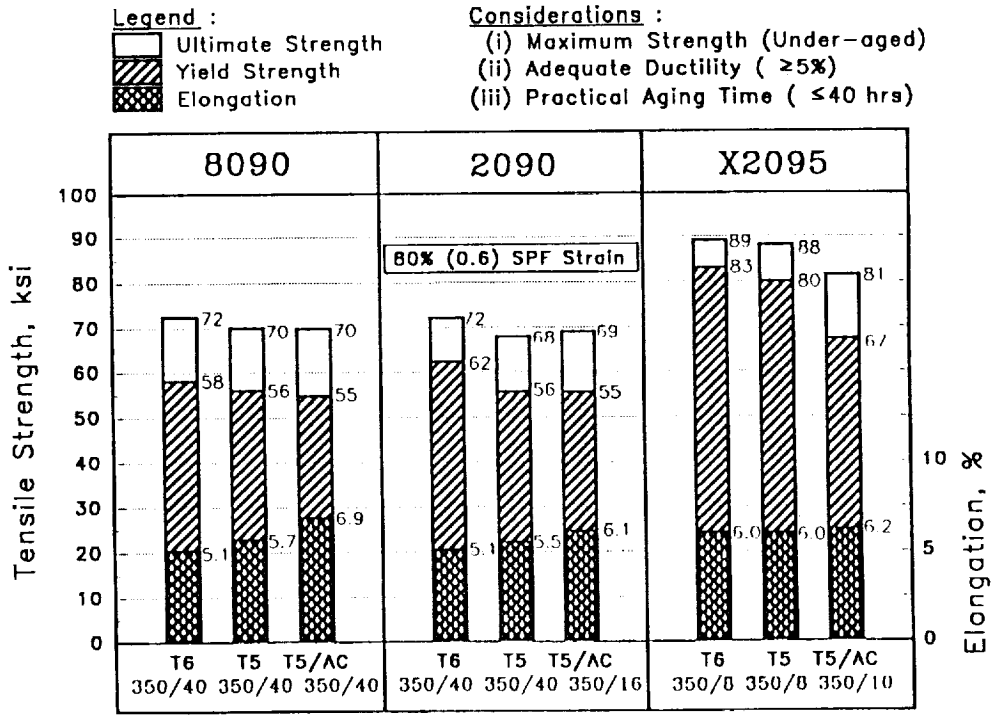
SPECIFIC PROPERTIES VERSUS TEMPERATURE FOR SELECTED AL ALLOYS IN T8 TEMPER



EXPERIMENTAL VERIFICATION OF SUPERPLASTIC FORMING PROFILE



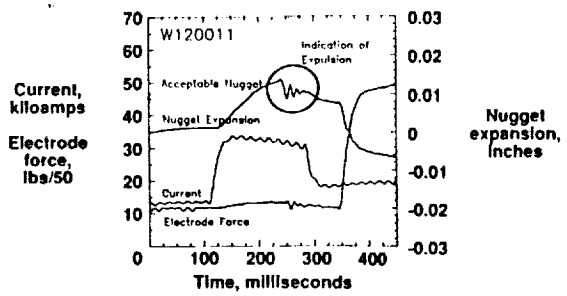
OPTIMUM POST-SPF PROPERTIES OF AL-LI ALLOYS



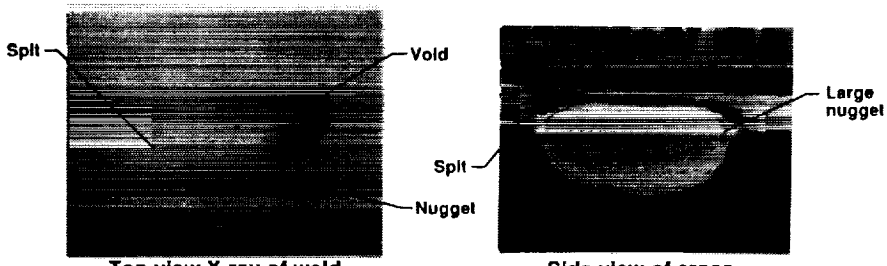
CHARACTERIZATION OF RESISTANCE SPOT WELDS

8090 T-6 to 2090 T-8E50

Spitting, High strength (1603 lbs overlap shear)



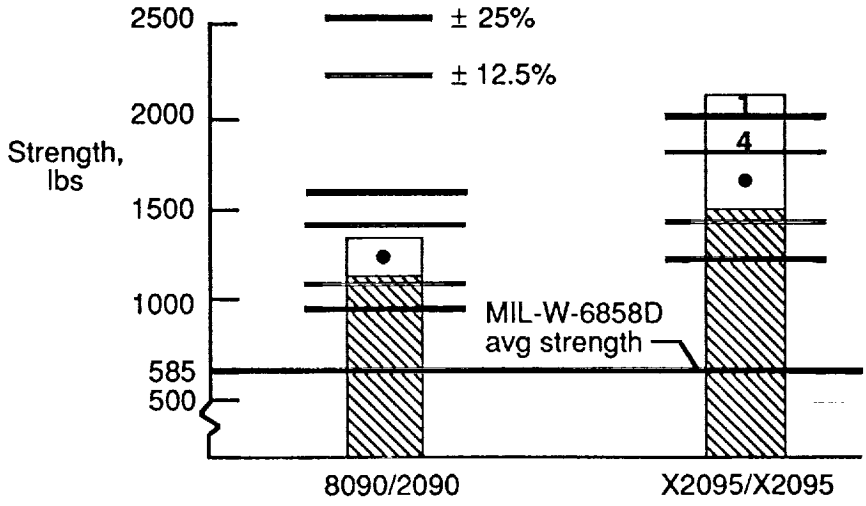
Feedback from welder



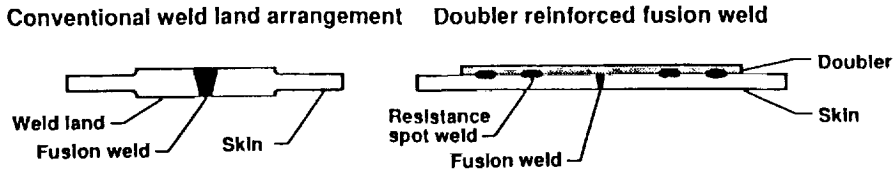
Top view X-ray of weld

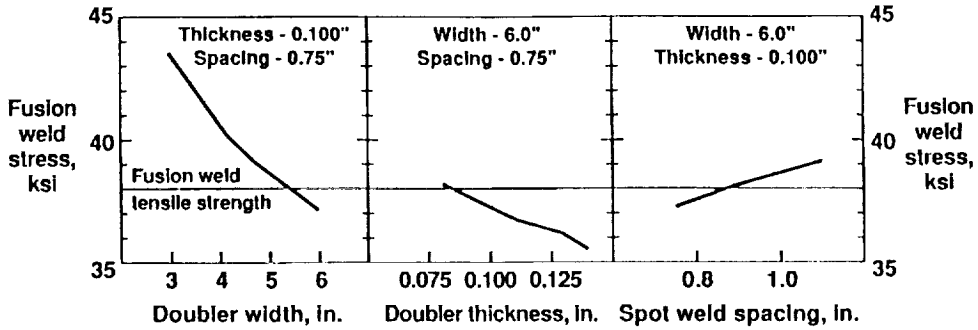
Side view of cross-sectioned weld

RESISTANCE SPOT WELDS OVERLAP SHEAR STRENGTHS



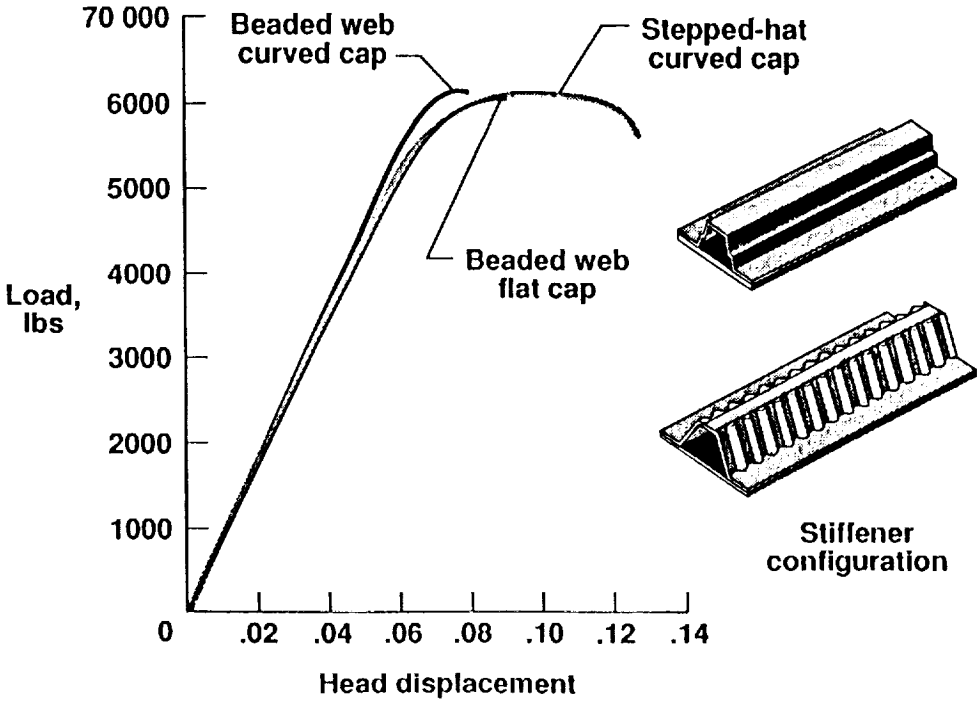
BUILT-UP STRUCTURE APPROACH TO REINFORCE FUSION WELDS





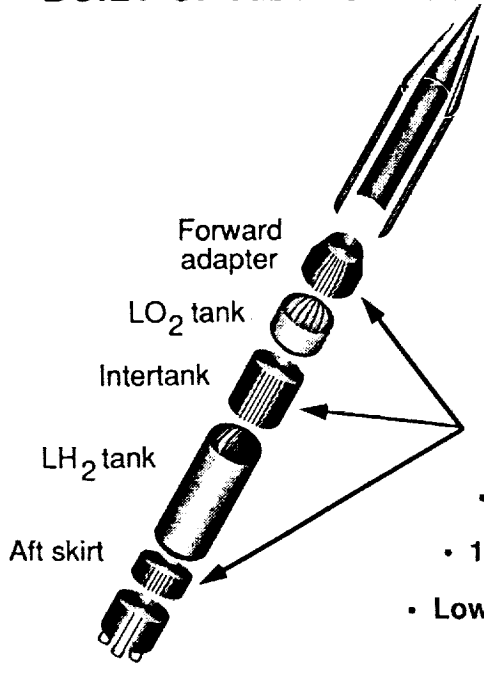
2090-T6(SPF)/2090-T8 Al-Li COMPRESSION PANELS

Tested at NASA LaRC



SUPERPLASTICALLY FORMED Al-Li MULTIPLE STIFFENED PANEL

BUILT-UP AL-LI STRUCTURES FOR NLS



- SPF stiffeners
- Reduced part count
- Minimum machining
- RSW assembly
- 15% weight savings
- Lower fabrication costs

PERFORMANCE BENEFITS USING AL-LI (G.D.)

- Direct substitution of Al-Li for conventional Al alloys can add 6000 lbs of payload to the baseline 11/2 stage vehicle. Redesigning the structure to take full advantage of the higher properties of Al-Li alloys could add >12000 lbs in payload savings.
- Weight savings of ~10% achievable by making the propellant tank of the 11/2 stage vehicle from Al-Li.
- Weight savings of ~5% achievable by making the adapter and thrust structure of the 11/2 stage vehicle from Al-Li.
- High raw material costs of Al-Li are the primary driver in selecting the appropriate fabrication approach.
- **Dependent on the material substitution approach and fabrication method the increased cost of using Al-Li could range from $0.5M to $4.0M per vehicle.**
- In the baseline 11/2 stage vehicle the cost performance for Al-Li ranges from $150/lb to $750/lb of payload increase compared with the current projected payload performance of $1500/lb using other alternatives.

ALDP BUILT-UP STRUCTURE FOR CRYOGENIC TANKS #3104

STATUS

- SPF OF Al-Li ALLOYS
  - Post-forming mechanical properties determined
  - 3' x 5' multiple stiffener panel formed
- RSW OF Al-Li ALLOYS
  - RSW schedules optimized using taguchi design of experiments
  - RSW strength of Al-Li alloys exceeds standard military specs
- STRUCTURAL TESTING
  - Crippling panels tested and shown to meet design req'ts
  - Stiffener design selected for column buckling panel
- COST/TRADE STUDIES
  - Cost analysis comparing roll forming, brake forming, extrusion and SPF fabrication methods near completion
- Current program focus assessing the benefits of Al-Li built-up dry-bay structures (intertank, fwd adapter, aft skirt)

8.3.2 Orbital Lessons Learned - A Guide to Future Vehicle Development by H. Stan Greenberg, Rockwell International