

Advanced Lightweight Freeze Tolerant Radiator for the EMU

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Outline

- **Technology overview**
- **Project objective**
- **Concept description**
- **Radiator weight**
 - Impact analysis
 - Coupon tests
 - Weight breakdown
- **Summary**
- **Acknowledgements**

Technology Overview

- o **Lightweight, freeze tolerant radiator to reduce EVA consumables**
 - o Currently, up to 8 lbm of water are sublimated during an EVA
 - o High launch costs (~ \$10,000/lb just to Earth orbit)



Background: Freeze Tolerant Radiator

- o **Current sublimator removals all heat loads**
 - o Highly variable metabolic loads
 - o Highly variable environmental loads
 - o Largest expendable in PLSS
- o **Radiators can provide heat rejection without expendables**
- o **This research developing an advanced, freeze tolerant radiator**
 - o Lightweight – about zero net wt added to the system
 - o Freezable to meet variable heat loads

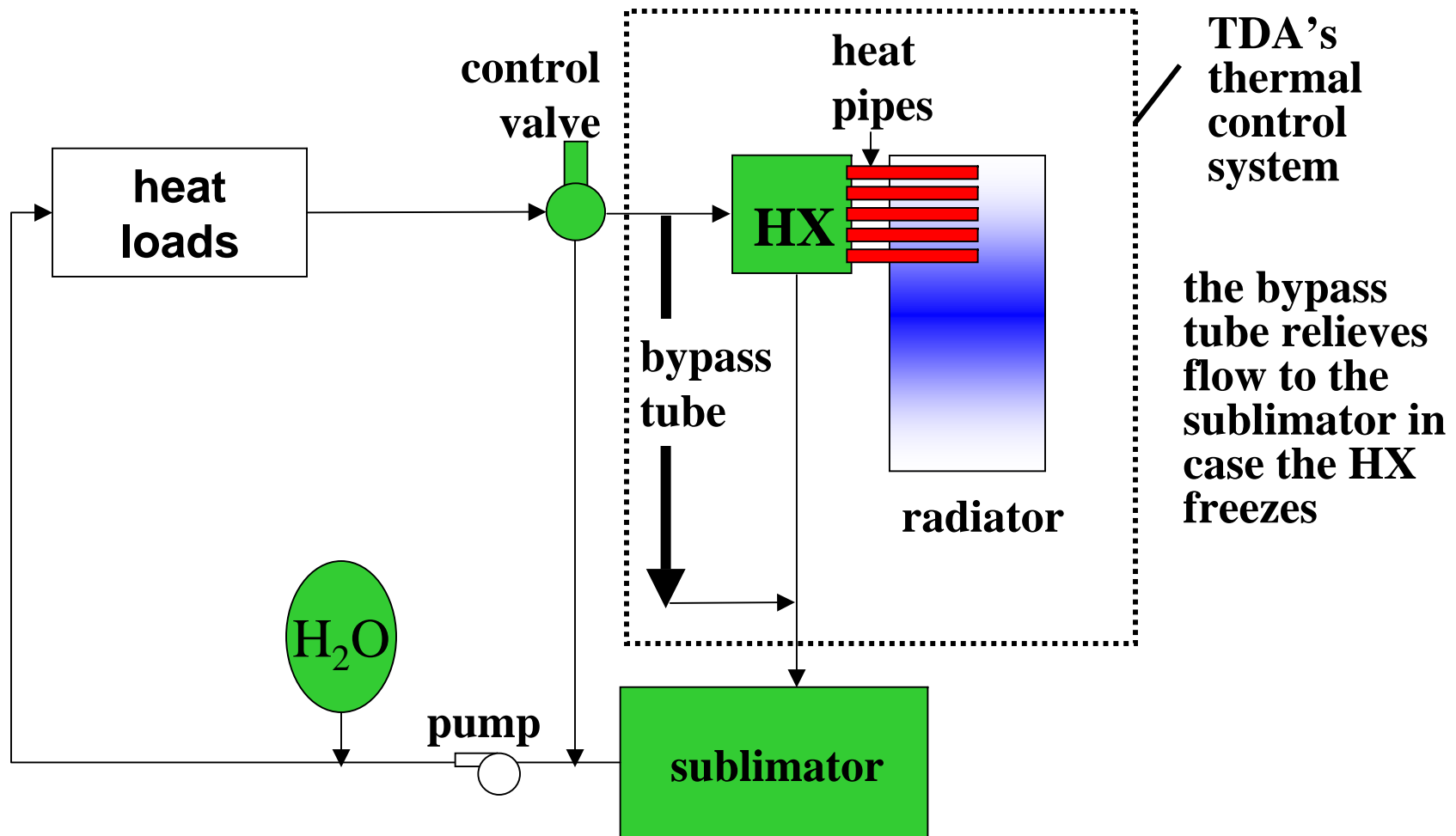
Radiator Heat Rejection Capacity

- **MAX** heat rejection to cold environment (~800 BTU/hr)
- **AVERAGE** heat rejection to average environment (~450 BTU/hr)
- **Total heat rejection during an 8 hr EVA**
 - the radiator rejects 3600 Btu/hr
 - the other half still rejected by the sublimator

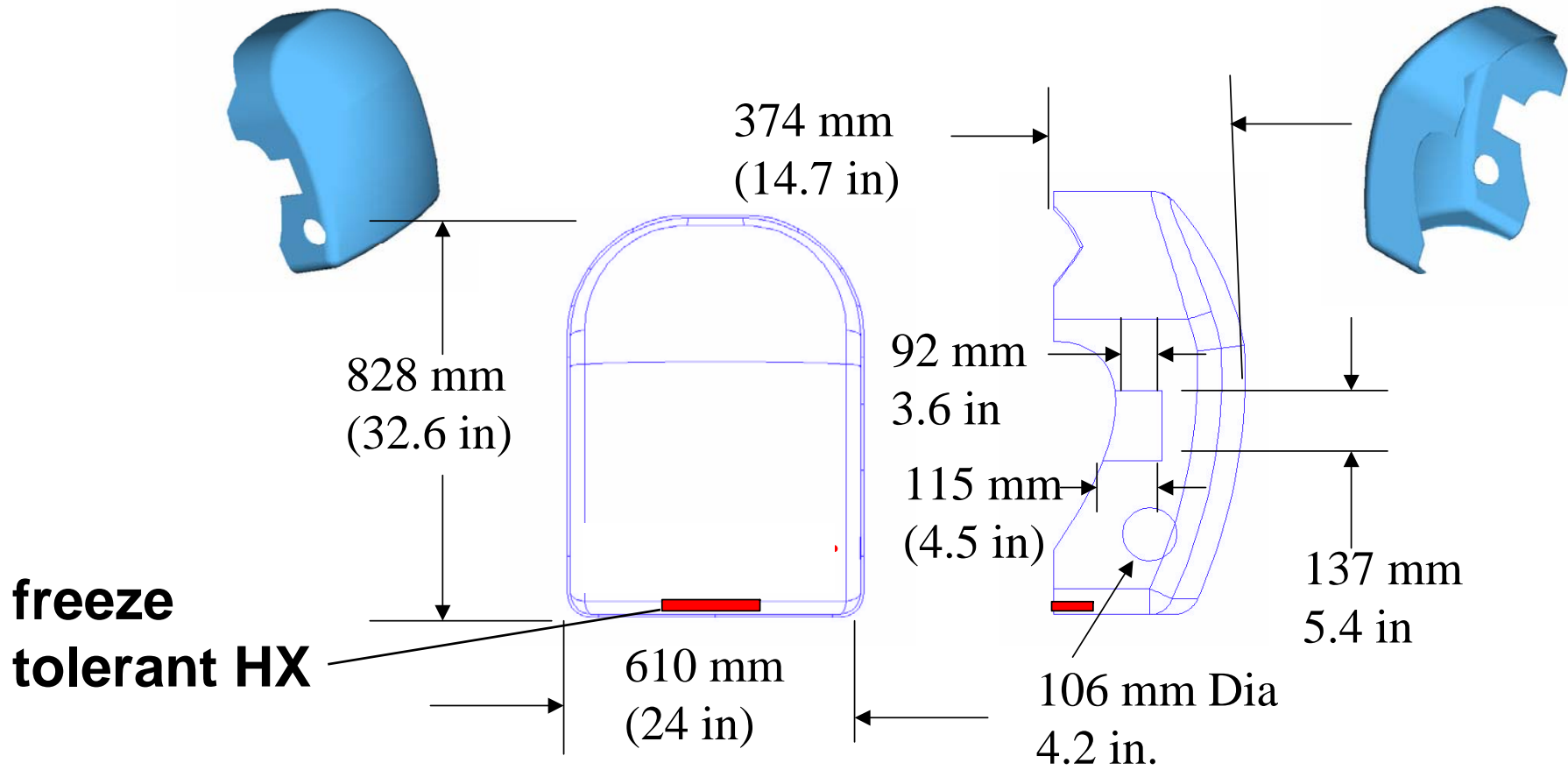
Project Objective: Make it Light!

- o **Previous freeze tolerant systems were too heavy!!!**
 - o Thick-walled tubes to withstand loads during freeze
 - o Really Heavy
 - o Copeland, et al developed thin-walled tubes
 - o inert gas column collapsed during freeze
 - o about 20 lbs
 - o And others...
- o **So, the key question—How to make a lightweight freeze tolerant radiator ?**

Freeze Tolerant Radiator Operating Schematic (or how does it work?)

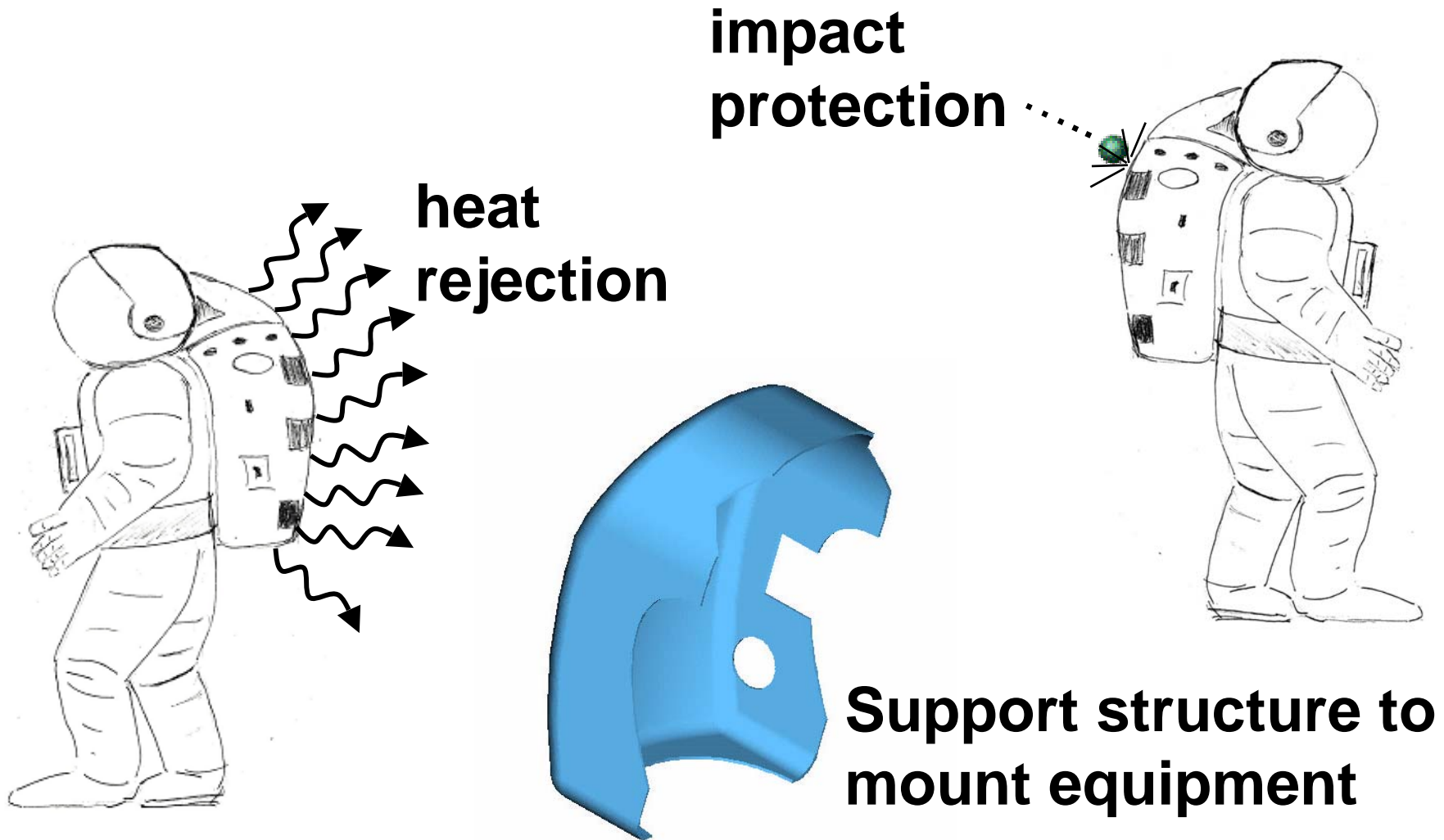


Advanced Flex PLSS Design



~9.5 ft² available for radiation

Multi-functional Radiator



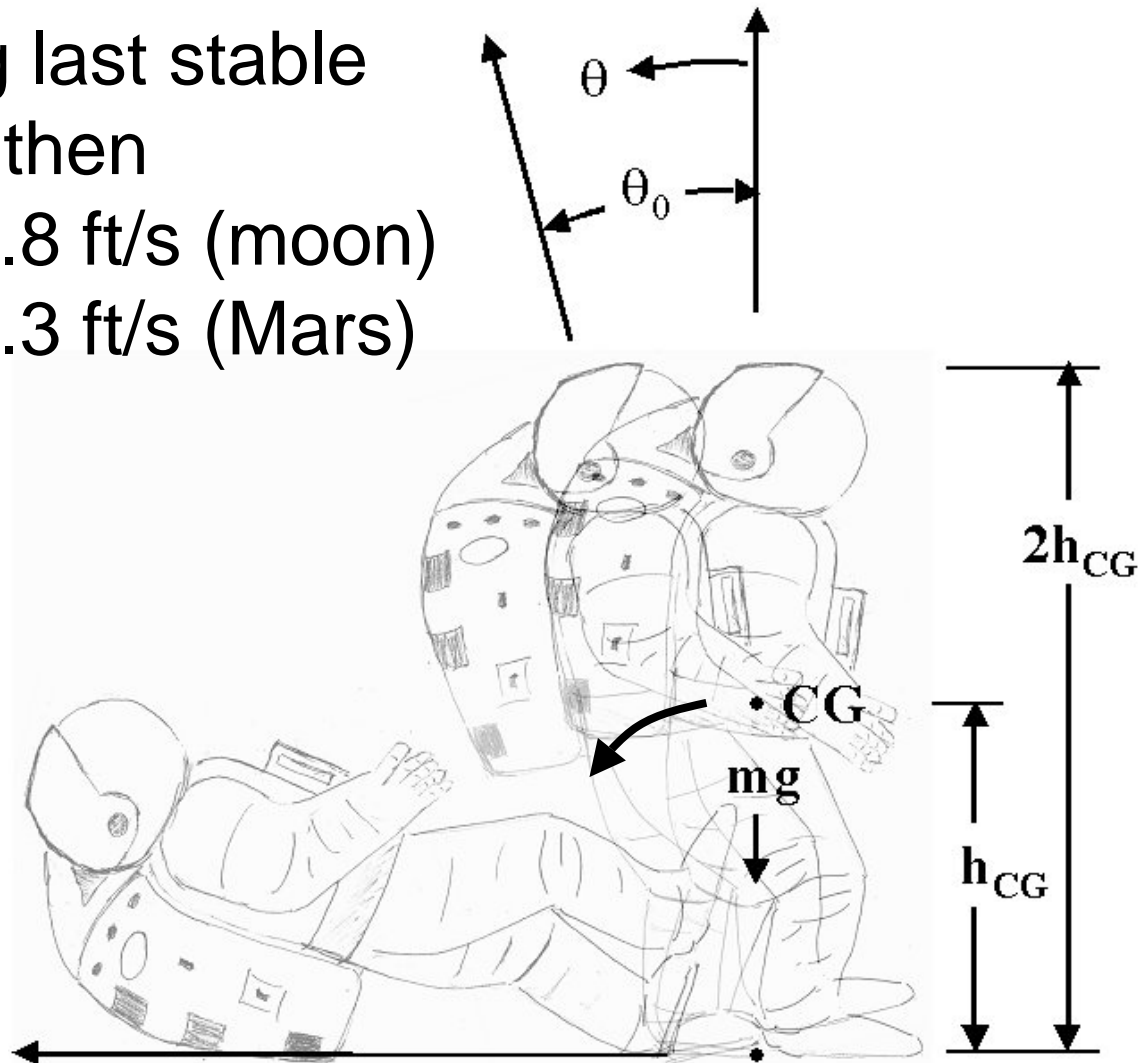
Impact defines wall thickness

Radiator Impact Analysis

Assuming last stable
pt of 15° , then

$$\Delta v = 4.8 \text{ ft/s (moon)}$$

$$\Delta v = 7.3 \text{ ft/s (Mars)}$$

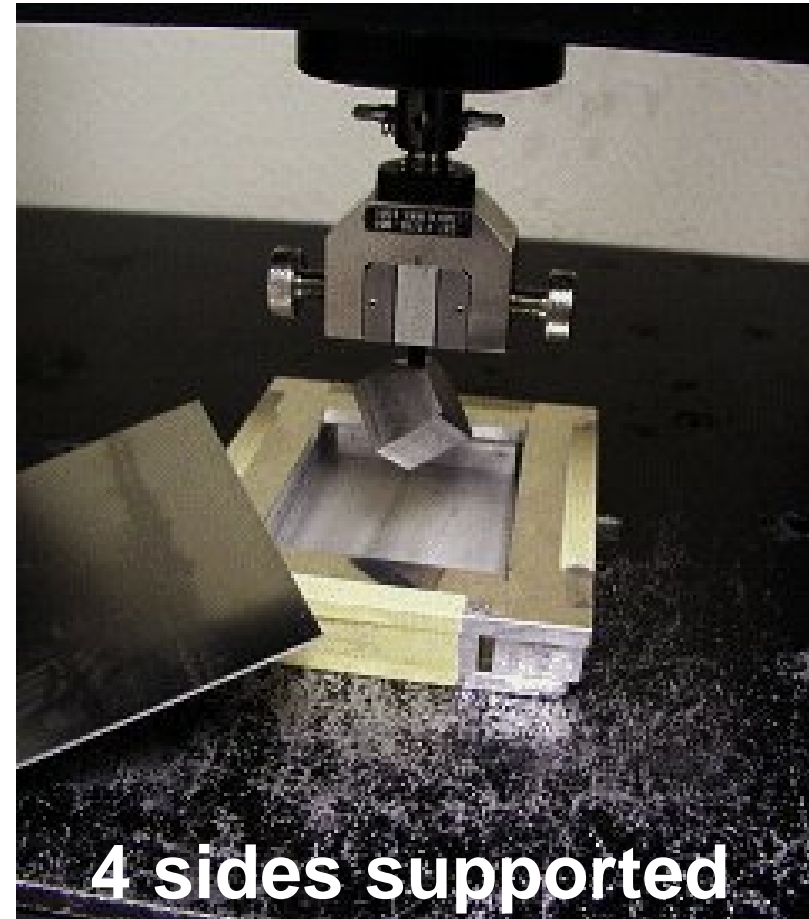
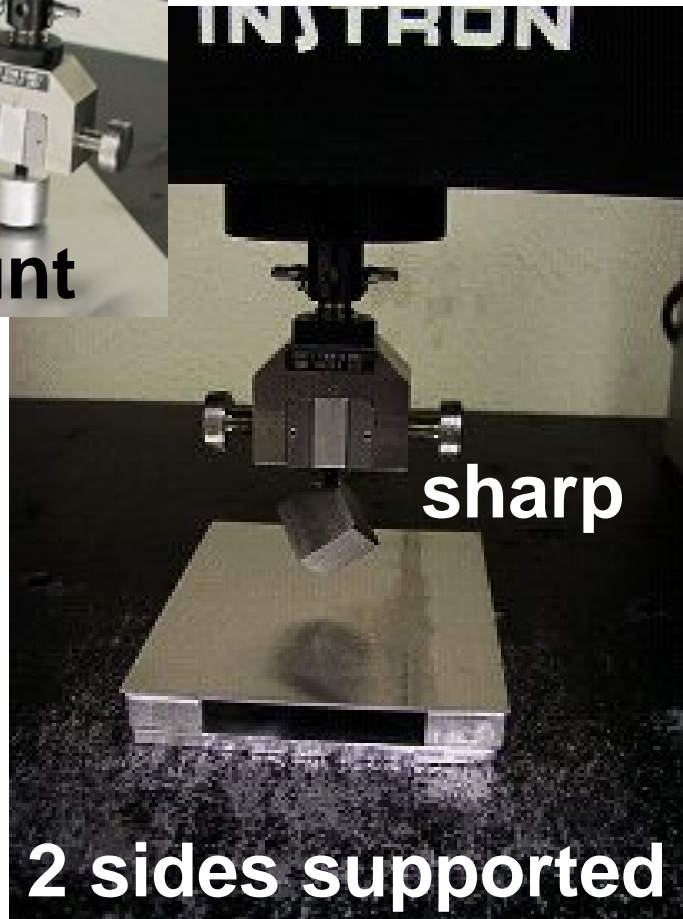


The inverted pendulum problem

Experimental Test Methodology

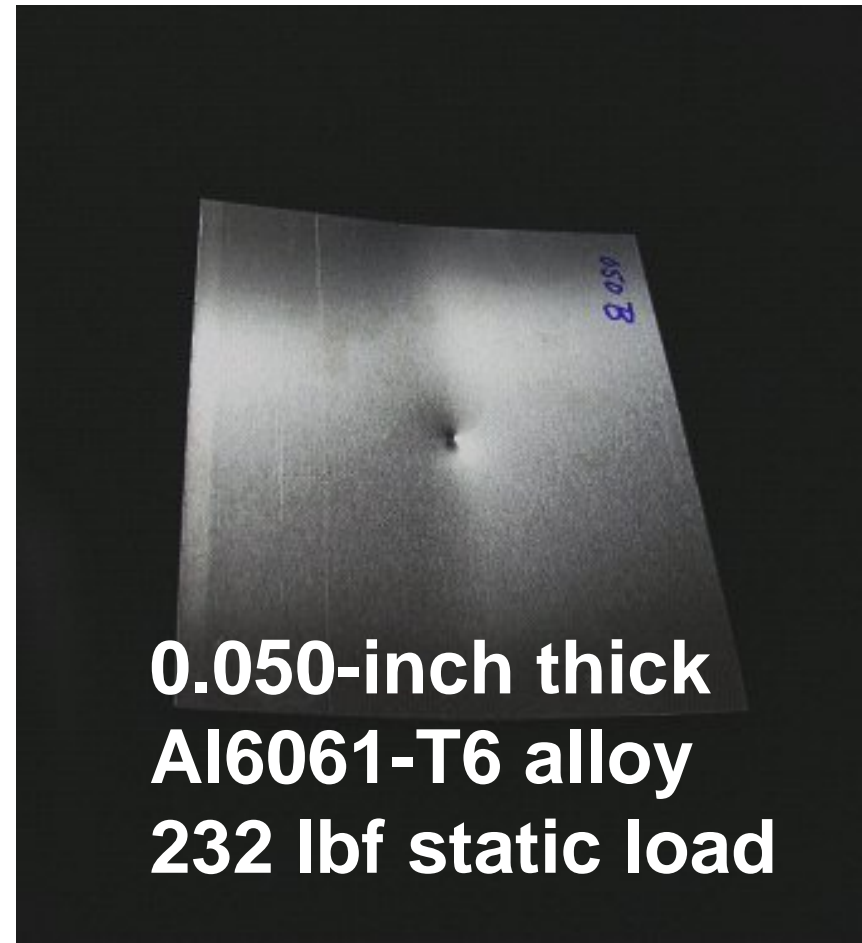
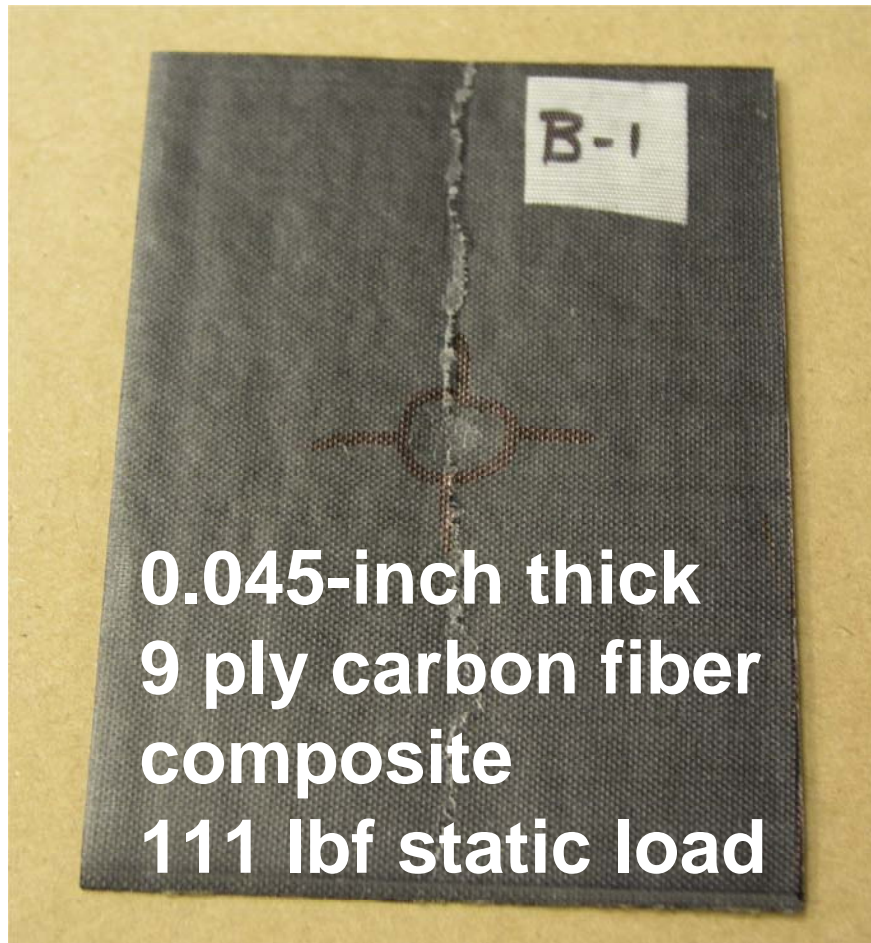
- **Fabricated test coupons**
 - Graphite fiber composite
 - Aluminum alloys
- **Instron tester applied static loads up to 400 lbf**
- **Coupons were simply supported (either 2 or 4 sides)**
- **Load applied until puncture or buckling occurred**

Test Setup

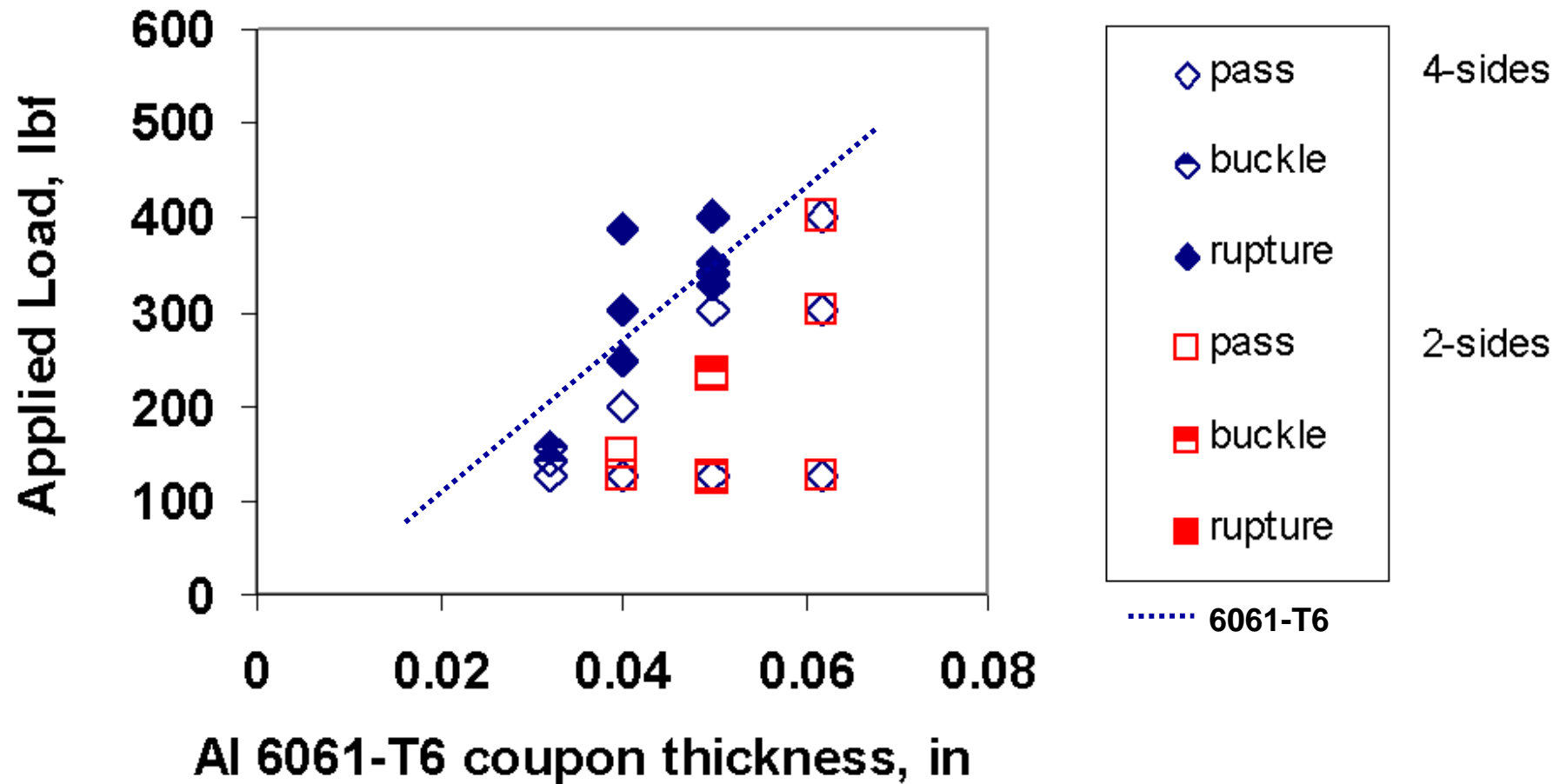


Post Test Coupons

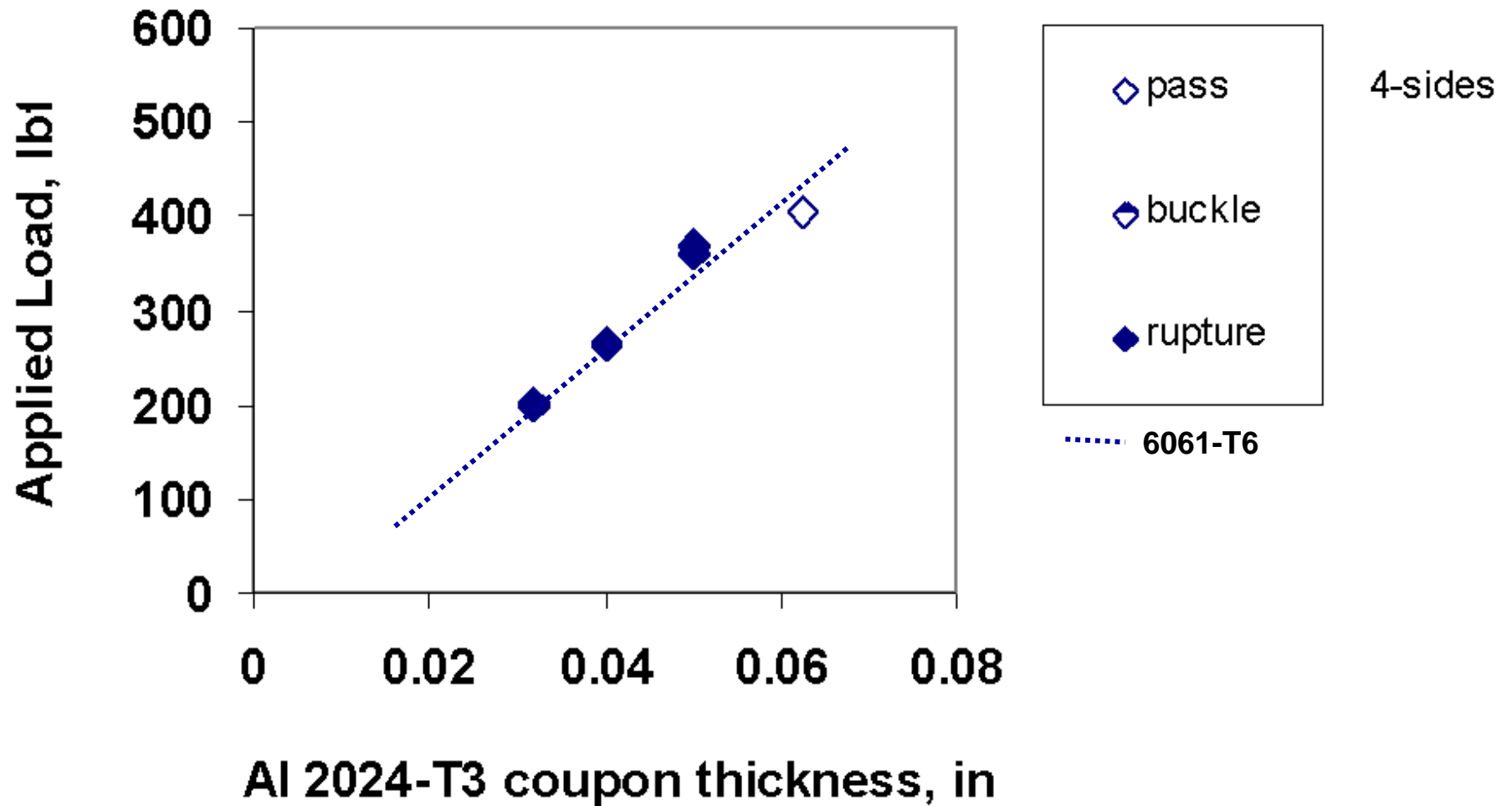
Simply Supported on Two (2) Sides



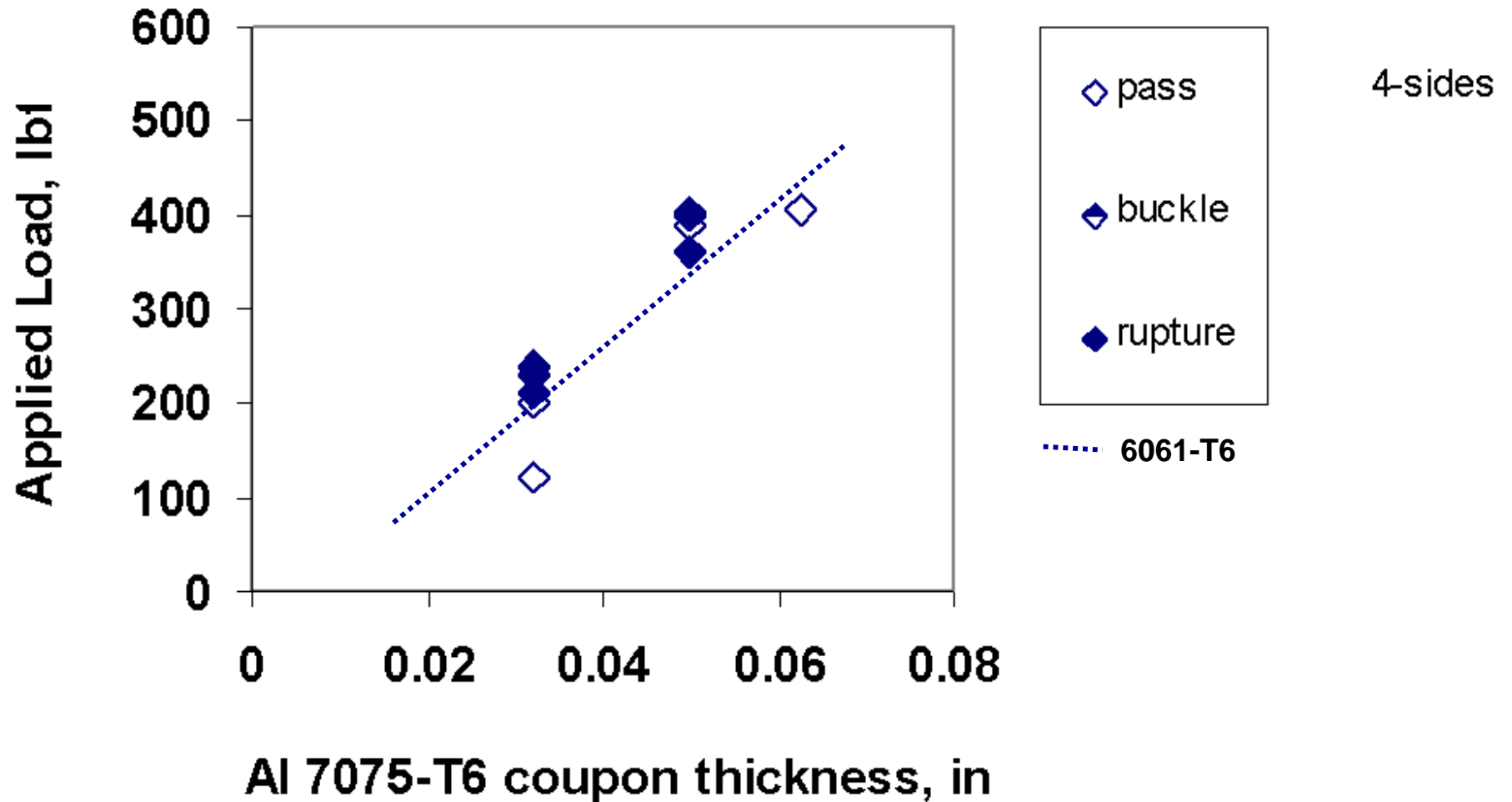
Al6061-T6



AI2024-T3



Al7075-T6



MIN Radiator Wall Thickness

Mission	Load, lbf	MIN wall thickness, in		
		Al 6061-T6	Al 7075-T6	Al 2024-T3
Earth orbit	125	0.025	0.021	0.025
Moon	300	0.048	0.048	0.048
Mars	450	0.0625	0.060	0.060



Chose 0.0625-thick Al6061-T6 for prototype construction

Estimated Radiator Weight Breakdown

	Earth Orbit	Moon	Mars
Radiator Shell	4.49	7.66	9.79
Equipment Mounts	0.60	0.60	0.60
Insulation	0.84	0.84	2.20
Inner Liner	0.59	0.59	0.59
Heat Exchanger	5.19	2.93	2.93
Loop Heat Pipes	0.78	0.78	0.78
Refrigerant	0.50	0.50	0.50
Total Weight	12.99	13.90	17.39
PLSS Weight Savings	(13.26)	(15.73)	(19.39)
Net Weight	(0.27)	(1.83)	(2.00)

Estimated PLSS Weight Savings

	E.O.	moon	Mars
Secondary O2 package cover	0.72	0.72	1.44
Tank cover	1.33	1.33	2.66
Upper shield cover	0.55	0.55	1.10
Thermal protection garment (5 sides)	3.40	3.40	3.40
PLSS internal support structure	7.26	9.73	10.79
Total Savings, lbm	13.26	15.73	19.39

Summary

- o **Freeze tolerant radiator has great potential**
 - o Light weight system
 - o Reduced expendables
- o **Development continues to progress**
 - o Design completed
 - o Prototype fabrication underway (actual weights to be obtained)
 - o Performance tests to be conducted in NASA JSC Chamber E in April 2006

Acknowledgements

- o **Luis Trevino, COTR for NASA Research Agreement Contract #NAS 9-03052**