

A Lightweight, Freeze Tolerant Radiator for an EMU

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Technology Overview

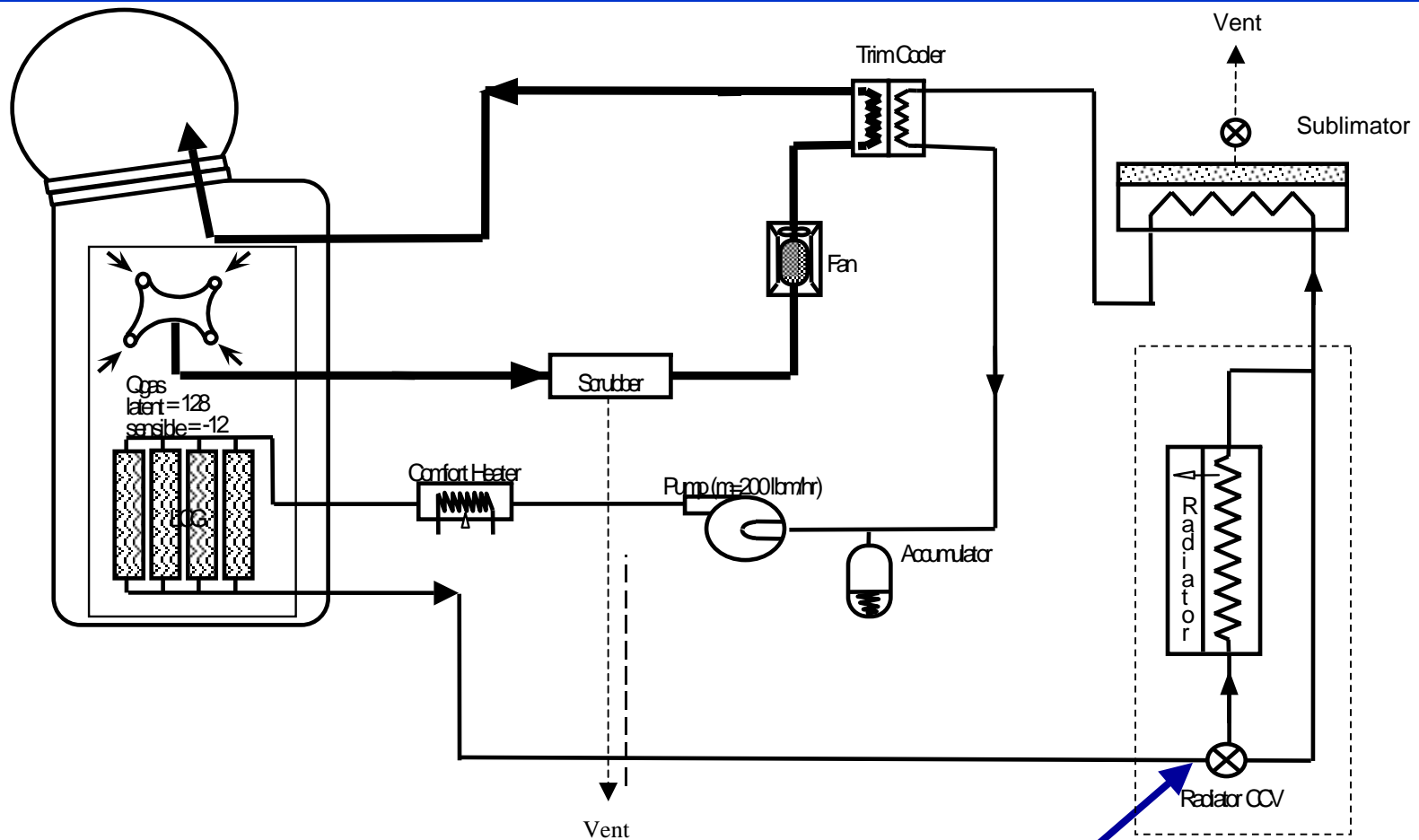
- **Lightweight, freeze tolerant radiator to reduce EVA consumables**
 - Currently, up to 8 lbm of water are sublimated during an EVA
 - High launch costs (~ \$10,000/lb just to Earth orbit)



Project Objective

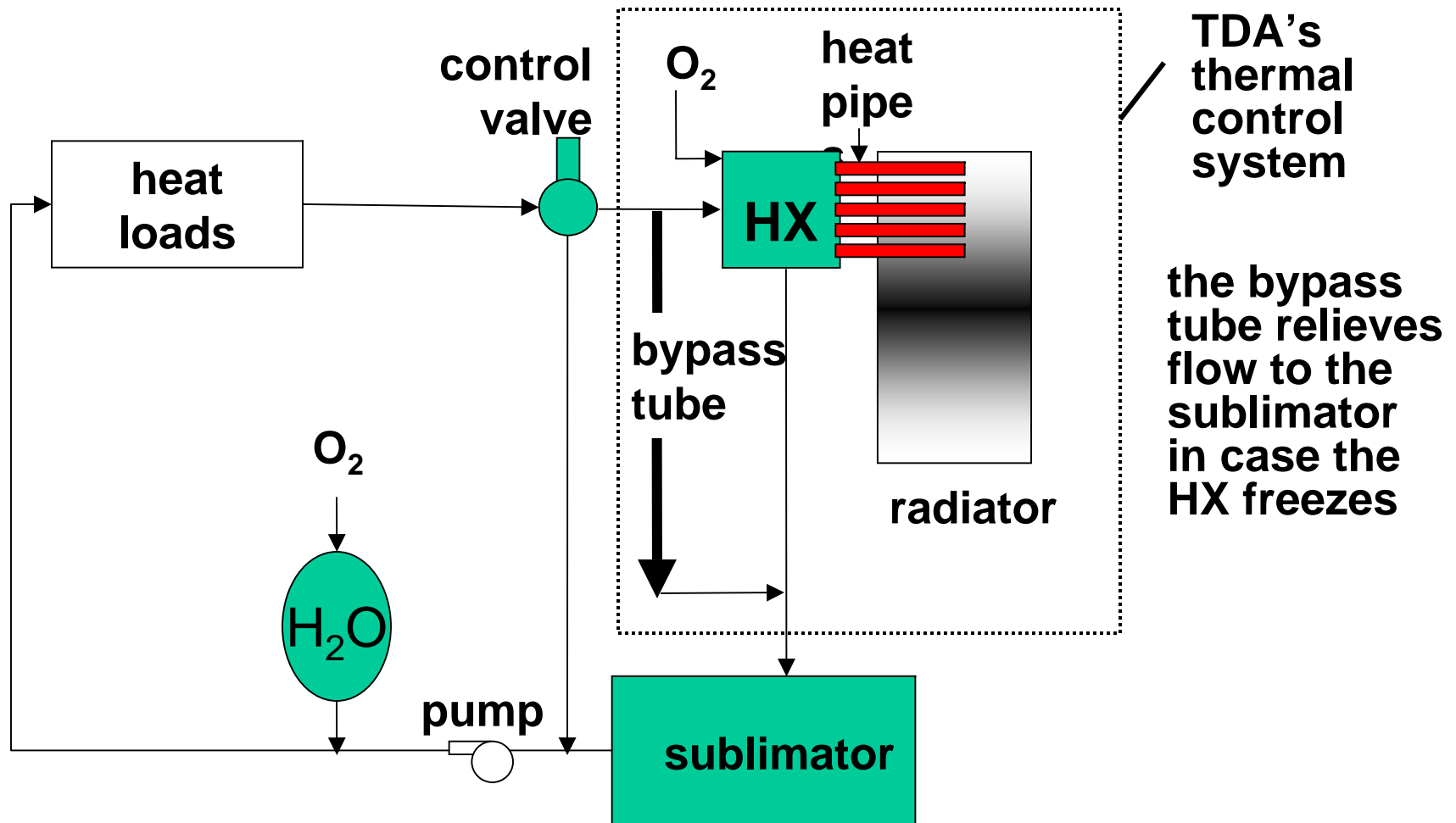
- **Develop a lightweight, freeze tolerant radiator**
 - Radiators can provide heat rejection to reduce expendables (about 3.6 lbm water per 8 hour EVA/person)
 - Freezable to meet variable heat loads
 - No increase in system mass

ATS MPLSS Model Flow Chart



Control valve also isolates radiator in hot environments

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

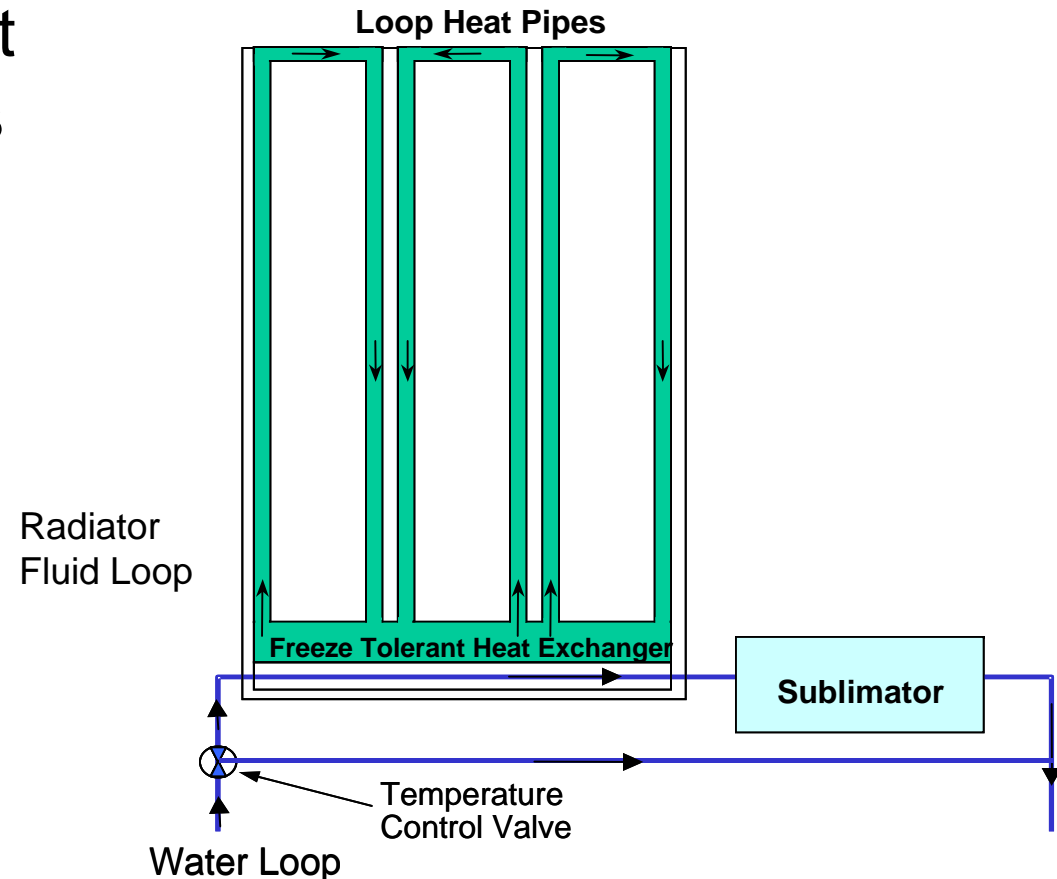


Radiator Requirements

- Freeze tolerant design
 - Radiator still operates and performs well with loss of one or two heat pipes
 - No damage to HX with **no** flow & cold environment
- Vary heat rejection from 200 to 850 btu/hr
 - Keep astronaut comfortable down to -290°F
 - Minimal heat gain in hot environments to $+220^{\circ}\text{F}$
- EO (“0” g), moon ($1/6^{\text{th}}$ g), & Mars (0.34 g)
 - Operate with 15° side tilt on Moon or Mars
- < 2 psi pressure drop thru water loop

Separate Fluid Loop for the Radiator

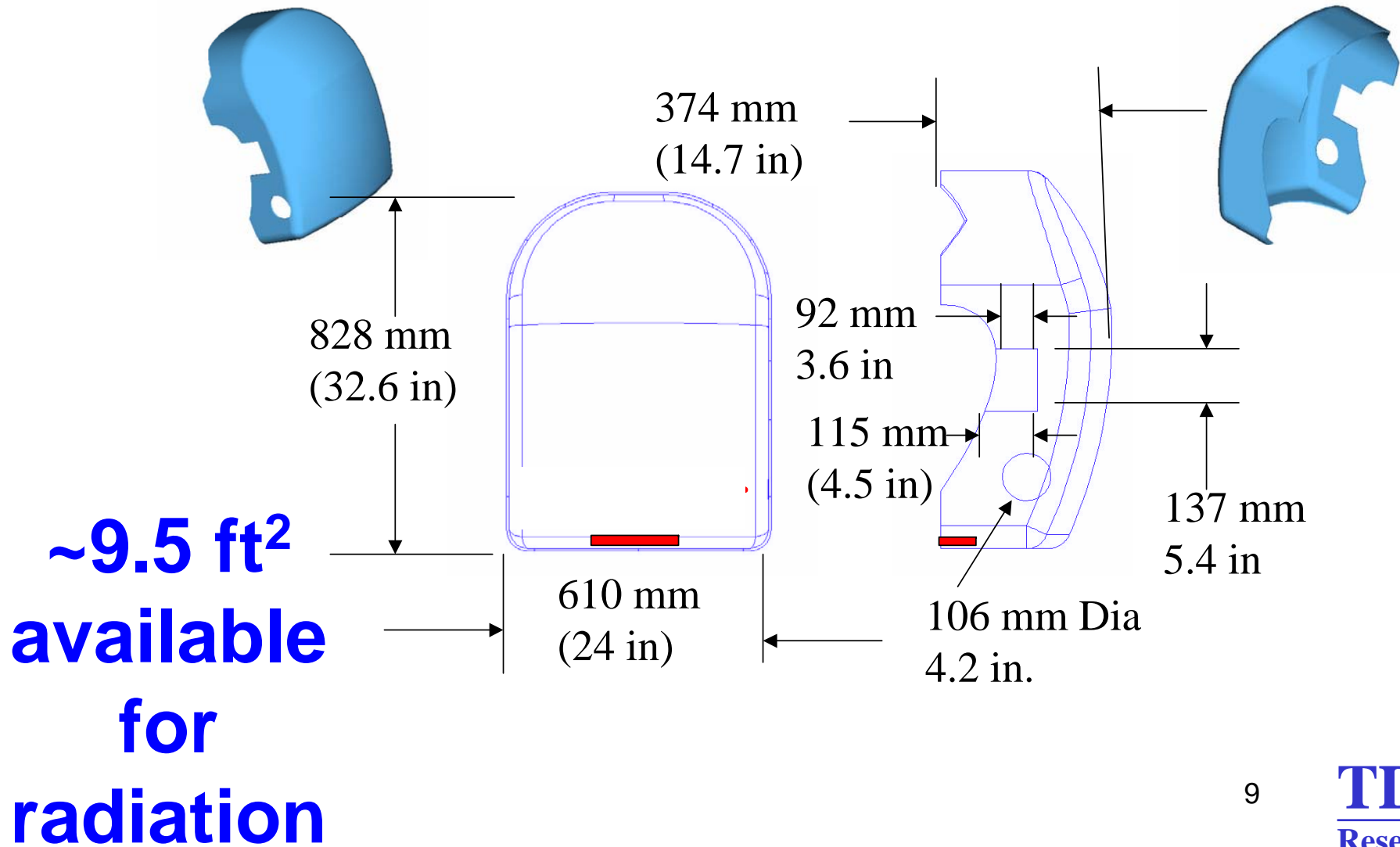
- Freeze tolerant heat exchanger removes heat from cooling water loop
- Loop heat pipes (5) move heat from heat exchanger to the radiator fin
- Completely passive system, no moving parts



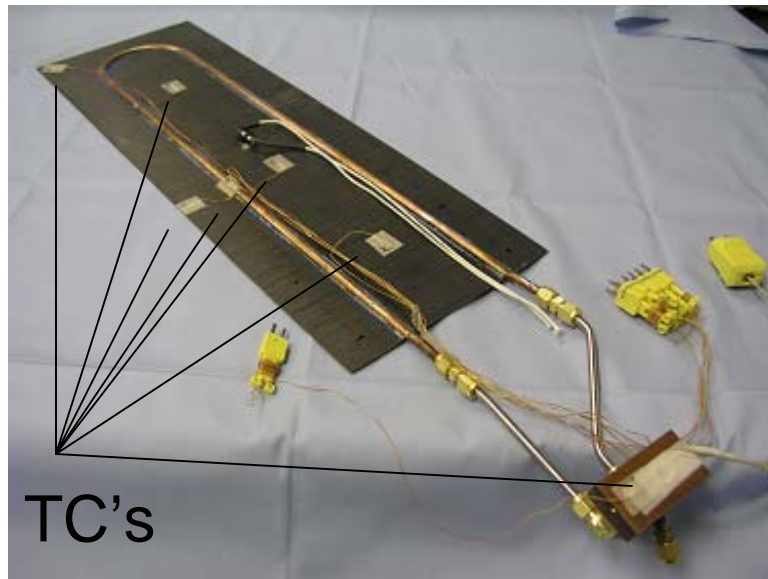
Freezing with Ice

- Water is the heat transport fluid in PLSS
 - Safe, proven, understood, good thermal properties
- BUT – High freezing point 32°F (0°C)
 - With only ~70°F inlet to radiator, very close to freezing point
 - Environment can be as low as –174°F E.O. and
 - 290°F moon
 - Water is difficult to thaw, once frozen
 - Large volume change on freezing (9.05% increase)

Advanced Flex PLSS Design



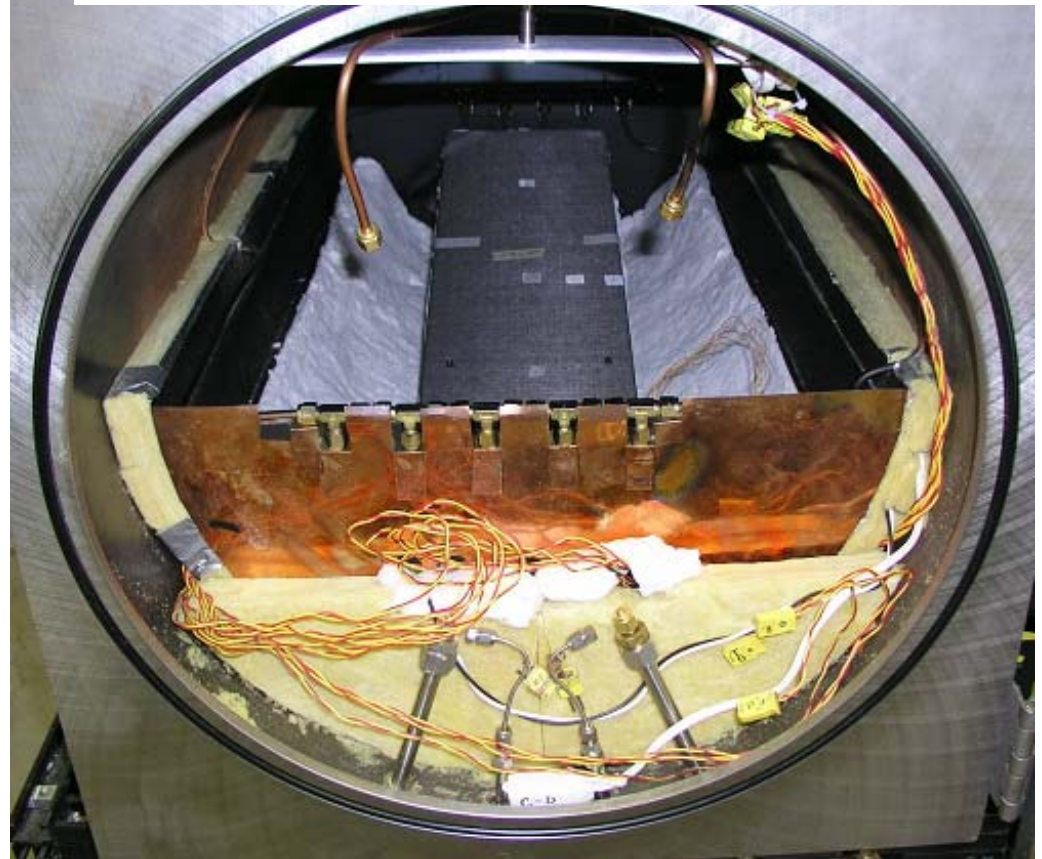
Advanced Radiator Tests



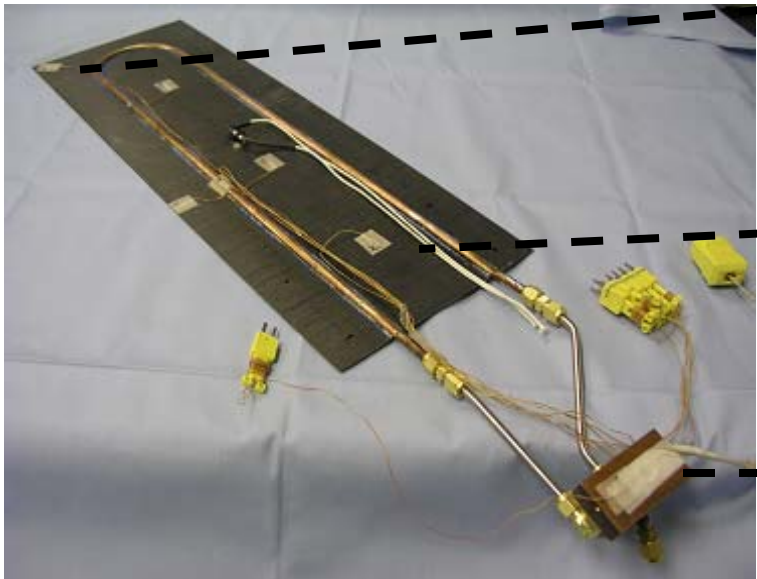
TC's

back view
– insulation removed

in the thermal vacuum chamber



HX / Radiator Test Results

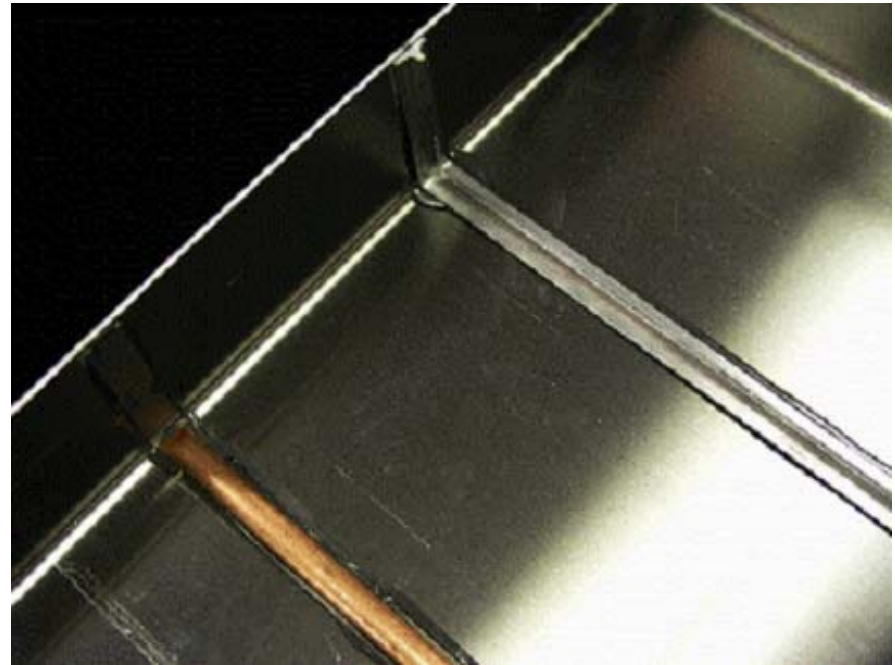


	<u>Low</u> <u>Heat</u> <u>Load</u>	<u>High</u> <u>Heat</u> <u>Load</u>
Sink temp	-298°F	-302°F
Upper radiator surface	-124°F	+37°F
Lower radiator surface	-85°F	+55°F
HX	-74°F	+70°F
Q/A, Btu/hr-ft ²	25.6	106

Large-scale PLSS Radiator Mock-up



34" long x 16" wide x 2" high
0.0625" thick Al 6061



Mock-up Impact Test Results (sharp object at 400 lbf load)

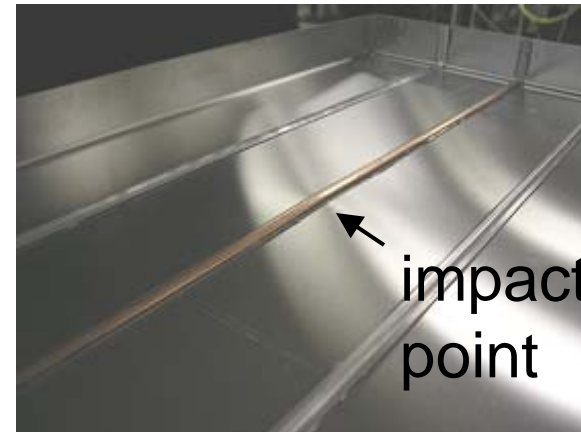
between the loop
heat pipes

on a loop heat pipe

outside
views



inside
views



Weight Budgets

	E.O.	moon	Mars
Radiator	4.49	7.66	9.79
Mounts	2.54	2.54	2.54
Insulation	0.84	0.84	2.20
Inner Liner	0.59	0.59	0.59
Heat Exchanger	5.19	2.93	2.93
LHP's	0.78	0.78	0.78
Refrigerant	0.50	0.50	0.50
Total Weight, lbm	14.93	15.84	19.33
PLSS wt savings			
Net Weight, lbm	(13.26)	(15.73)	(19.39)
(excludes H₂O savings)	1.67	0.11	(0.06)

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

- **Freeze tolerant heat exchanger with loop heat pipes**
 - Relatively lightweight system
 - Reduced water consumption
- **Critical tests and analyses justify continued development**