LAT Environmental Test Planning

7-8 September 2005

LAT Thermal-Vacuum Test Plans

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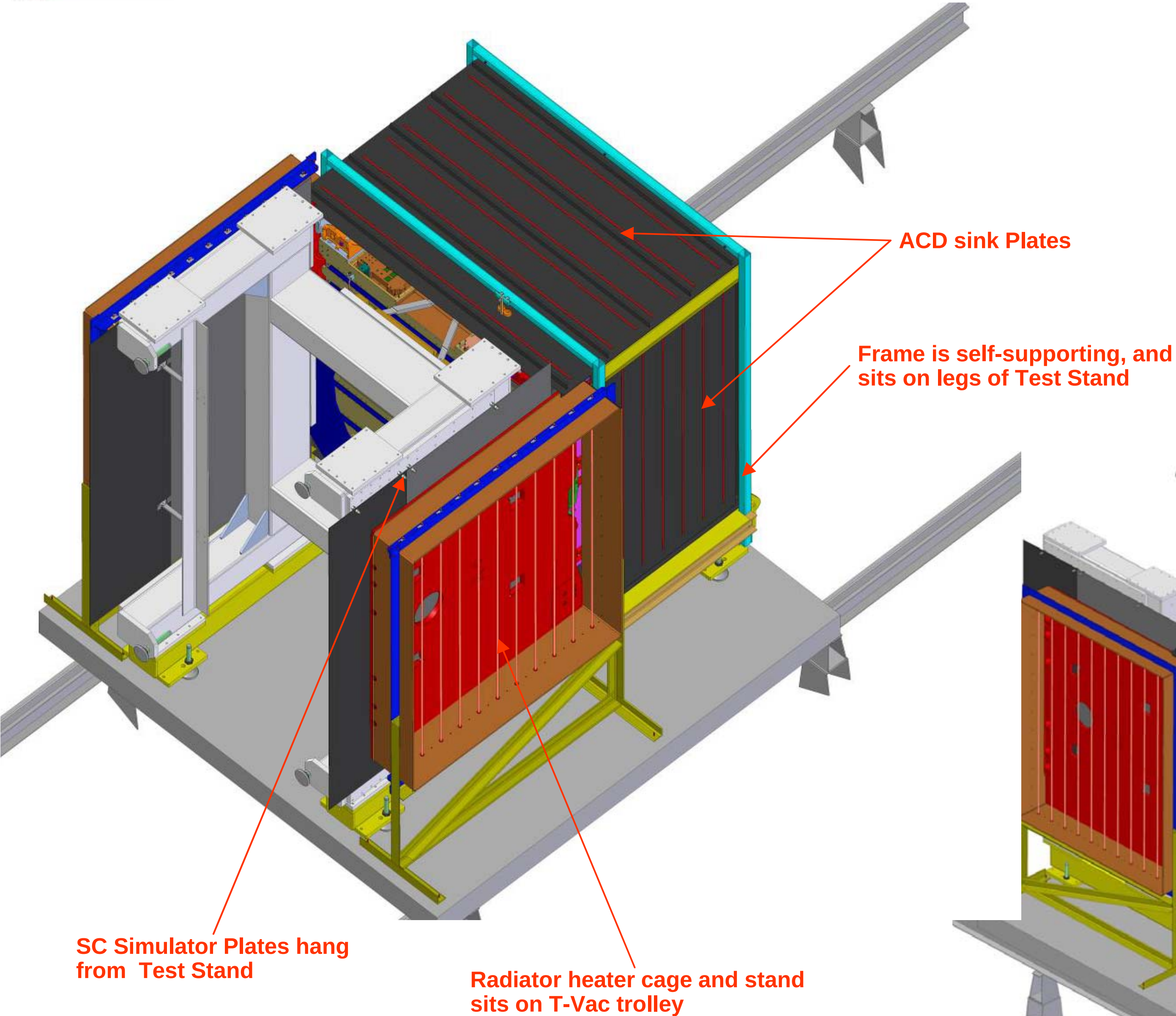
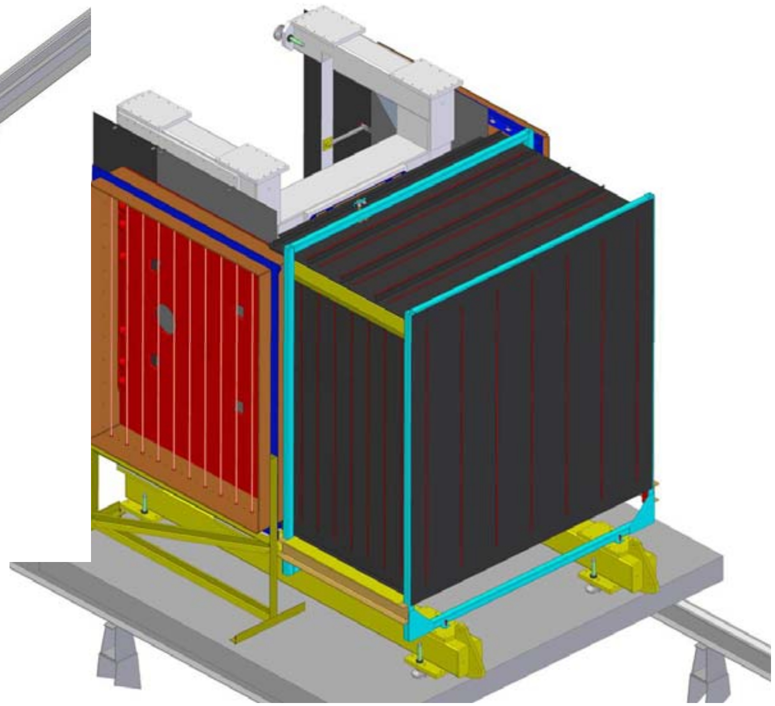
Outline

- Specialized Test Equipment key design requirements
- STE electrical layout and details
- STE mechanical design and integration with LAT and MGSE
- STE validation test plans
- Summary

Thermal-Vacuum Configuration Assembly





Specialized Test Equipment Key Design Requirements

- Three primary pieces of STE hardware
  - Radiator Heaters and Support Cage
    - Infrared heater cages will be used as heat sources to simulate the environmental heat loads on the Radiator outer surfaces. These are comprised of Cal-Rod heaters, supported in open cages. The following requirements apply to the heater cage design.
  - SC Simulator Sink Plates
    - Provides an equivalent sink environment for the Radiator inside faces during thermal-vacuum testing.
  - ACD Sink Plates and Support
    - Provides an equivalent sink environment for the ACD X-, Y-, and Z-faces during thermal-vacuum testing.
- General requirements for all thermal STE
  - All materials must be low outgassing and compatible with thermal-vacuum environment
  - Construction must not have trapped volumes or un-re-clean-able volume or surfaces
  - Prior to use, all STE shall be vacuum-baked by operating the heaters at their maximum expected power level and raising all STE temperatures to 75 degC, min, until their outgassing level is below 5 Hz/hr/hr

Radiator Heater Cage and Support Requirements

- Radiator Heaters and General Configuration Requirements
  - Min power required for all heaters in one frame is 2400 W, divided evenly over all heaters
  - Cal-rod heaters kept small to reduce view factor from Radiators
  - Heaters are low mass to speed heating/cooling rates
  - Heaters have medium-to-high emissivity surfaces
  - The array of cal-rod heaters shall be 6-12 inches from the radiating face of the Radiators
  - The spacing of the cal-rods shall be no greater than 6.5 inches
  - Cal-rod heaters shall be oriented perpendicular to the Radiator VCHP's, with a minimum radiating length to cover the entire width of the Radiator
  - Two cal-rods at each end of the Radiator shall be powered independent of the center rods to account for end effects (3 zones/Radiator, total)
  - Temp distribution imposed on Radiators by cal-rods shall be uniform to within 5 degC
- Support Cage and Frame Requirements
  - Support frame thermally isolates heaters from each other and off the support structure
  - The frame shall accommodate temperature excursions in the heaters from -150 degC, min, to 800 degC (TBR), max
  - Frame capable of functioning down to -150 degC (TBR) with heaters at their peak temp
  - Frame includes a cowling to block view of heaters to LAT. Outer surface: MLI, inner surfaces: polished and low-emissivity. Cowling 12" deep, covering entire Radiator
  - Frame is self-supporting off trolley floor
  - Frame is a low mass, low profile structure, to minimize obstructions between the Radiators and cold shrouds, and reduce view factor from LAT to the frame

SC Simulator Sink Plate Requirements

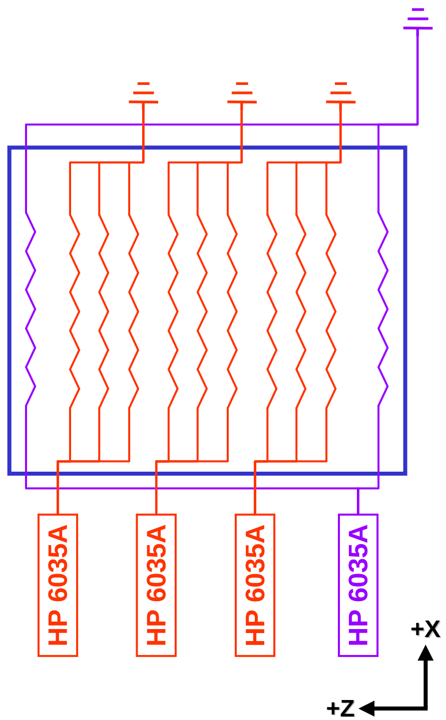
- **Panel Configuration**
  - Located in-board of each of the LAT Radiators. They provide an equivalent sink temp to simulate the combined influence of thermal backloading of SC and glancing views to the on-orbit space environment
  - One SC side sink plate forms one thermal zone, but the panel may be physically separated into two pieces to accommodate mounting around the Radiator struts
  - Max allowed temperature variation within a plate is 10 degC
  - The outer surface of the plates (facing the Radiator MLI blankets) must be coated with a high-emissivity surface with E > 0.8. The inner surface should be blanketed with MLI to reduce thermal coupling to the Test Stand.
  - Plates supported by Test Stand, with external support along the bottom and top edges
  - Support off Test Stand must allow for differential expansion/contraction of the sink plates, given a maximum design temperature differential of +/-150 degC
  - Plates must be 2-4 inches from the inner side of the Radiator stayclear
  - Plates must have accommodation for being lifted by a crane, laid flat, and stacked
- **Plate Size**
  - Active radiating area covering at least 95% of the surface of the Radiator
  - Max allowed thickness of the plates is 6 inches, including the panel and support hardware, heaters and cabling, and all other items on the panel
  - Min thickness of the bare plate is aluminum 0.09 inches thick

ACD Sink Plates and Support Requirements

- Configuration
  - Located out-board of each of the surfaces on the +Z, +Y, -Y, +X, and –X of the ACD.
  - Each panel covers one face of the ACD with a view factor of nearly one and consists of one zone that is controlled independent of the other ACD panels. While the five ACD plates must be thermally isolated, they can be physically connected.
  - The maximum allowed temperature variation within a plate is 10 degC.
  - Sink plate faces coated with a moderate emissivity surface with E = 0.5 +/-0.05
  - The inside surface of the sink plates must be 2-4 inches from the ACD stayclear
  - ACD sink plates must be self-supporting, with external support only on perimeter edges
  - The plates must have accommodation for being lifted by a crane, laid flat, and stacked
- Plate Size
  - Active region of plates at least 95% of the area of the surface it is viewing
  - Min thickness is aluminum 0.09 inches thick
- Support Structure
  - The support structure must thermally isolate each of the sink plates from each other and from the structure, to reduce the conductive heat losses
  - The support must have a small view factor from the sink plates
  - The support must be free-standing, and capable of moving as an assembled unit
  - Includes leveling feet to align the sink plates in their correct location
  - Must allow for differential expansion/contraction of the sink plates, given a maximum design temperature differential of +/-150 degC. It must allow for free motion of the panels to prevent buckling.

Radiator Heater Cage Electrical Layout

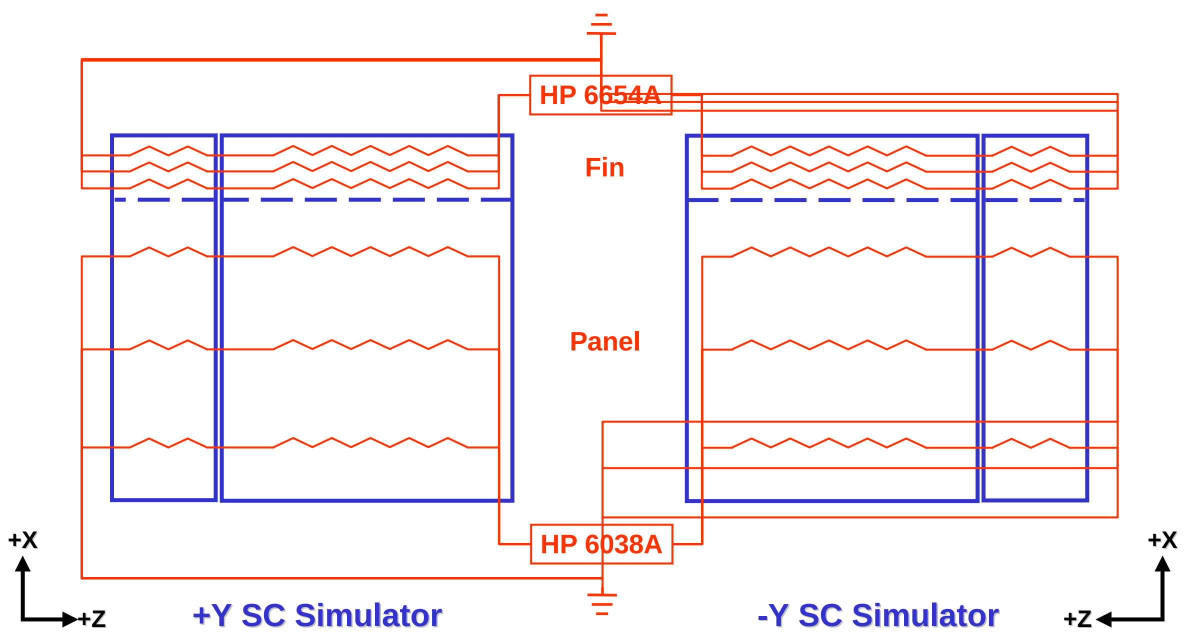
- Four power supplies for each Heater Cage
  - One circuit for the two end heaters
    - Ends will see different radiation environment, and will need to be adjusted independent of the heaters in the field
    - This circuit is sized to deliver more power
  - Field heater circuits are identical
    - 3 circuits of 3 heaters each
    - Number of power supplies is set by max power per supply, not any adjustability req
- Redundancy
  - Layout is 9-for-11 redundant
    - One end heater and one field heater could open and we could still complete T-Vac test
    - Heater circuits include design margin to handle increased power to compensate for lost heaters
    - Cal-Rod failure is typically an open circuit—this design cannot compensate for any shorts to ground
  - Loss of any heater would produce a cold spot in the equivalent sink temperature environment that the Radiator sees
    - This would likely need to be added to the LAT T-Vac thermal model to ensure good model correlation
  - Loss of a heater will be straightforward to identify and localize



+/- Y Radiator Heater Cage

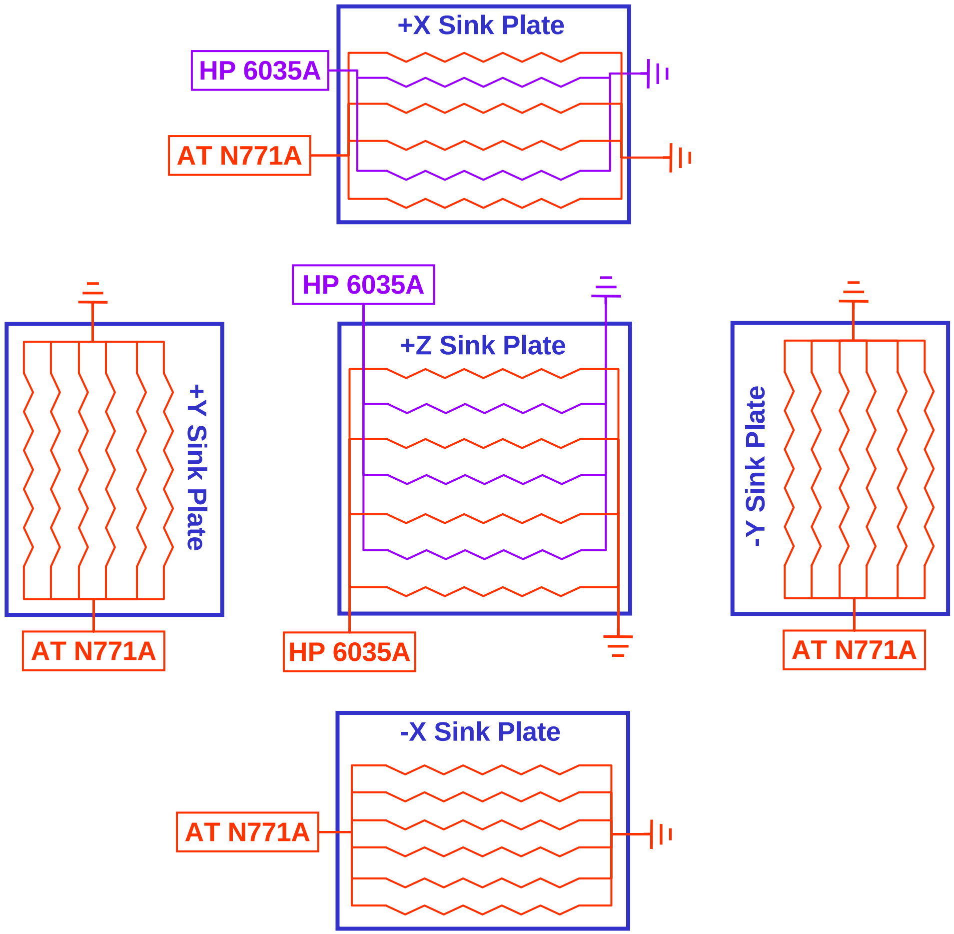
SC Simulator Electrical Layout

- Two power supplies total
  - One circuit for fin heaters on both SC Simulator plates
    - The fins extend beyond the back of the Radiator, and are used to radiatively cool the SC Simulator
    - This is where almost all of the heat is lost, so concentrating heaters here reduces temperature variations in the rest of the panel
  - One circuit for panel heaters on both SC Simulators
    - This is a very low power circuit, just enough to compensate radiative heat loss to the Radiators
- Redundancy
  - Each circuit is 2-for-3 redundant
    - Either circuit could lose one heater on each SC Simulator and still function
    - Shorts to ground are not expected and cannot be compensated for
  - Loss of a heater would have little impact on thermal environment of LAT



ACD Sink Plate Electrical Layout

- Five temperature zones—one per plate
  - +X and +Z Sink Plates need 2 power supplies each
    - +X and +Z faces of LAT see higher equivalent sink temps during T-Vac testing, to simulate sun and earth
    - Extra power supplies are needed to produce the power needed
    - Each plate is intended to be isothermal, despite having 2 power supplies
  - +Y, -Y, and –X Sink Plates are require only 1 supply each
    - 6 strip heaters per circuit are needed to reduce temp gradients in the plate
- Redundancy
  - +X and +Z Plates have interleaved heater strips
    - This produces 5-for-6 redundancy
  - +Y, -Y, and –X Plates are each 5-for-6 redundant
  - The thermal effect on the LAT of 1 lost heater is negligible



STE Circuits and Power Requirements

Thermal-Vacuum Specialized Test Equipment Heater Circuits

STE Circuit	Panel Req's		Panel Heater Sizing					Total Circuit				Power Supply and Feeds				
	Panel Power	With Margin (1)	# Htr Strips	Pwr/ Strip	Clayborn P/N	Strip Res.		Total Res. (3)	Volt.	Current	Pwr	Qty	Model No.	Max Volts	Max Current	Pwr
	W	W		W		Ohm/ft	Ohm/strip (2)	Ohm	V	A	W			V	A	W
+Y Rad Htr Cage *(set to PS max power)*											**4000**	**4**				
Circuit 1		*1000*	3	333			150	50	224	4.5	1000	1	HP 6035A	500	5	1000
Circuit 2		*1000*	3	333			150	50	224	4.5	1000	1	HP 6035A	500	5	1000
Circuit 3		*1000*	3	333			150	50	224	4.5	1000	1	HP 6035A	500	5	1000
End Circuit		*1000*	2	500			150	75	274	3.7	1000	1	HP 6035A	500	5	1000
+Y Rad Htr Cage *(set circuits to 200 volts)*											**2933**	**4**				
Circuit 1			3	333			150	50	*200*	4.0	800	1	HP 6035A	500	5	1000
Circuit 2			3	333			150	50	*200*	4.0	800	1	HP 6035A	500	5	1000
Circuit 3			3	333			150	50	*200*	4.0	800	1	HP 6035A	500	5	1000
End Circuit			2	500			150	75	*200*	2.7	533	1	HP 6035A	500	5	1000
SC +Y Sim	**186**	**247**									**247**	**2**				
Fins	166	221	6	37	C-28-3	4	24	4.0	29.7	7.4	221	1	HP 6654A	60	9	540
Panel	20	27	6	4	C-28-2	16	96	16.0	20.6	1.3	27	1	HP 6038A	60	10	200
SC -Y Sim	**186**	**247**									**247**	**0**				
Fins	166	221	6	37	C-28-3	4	24	4	30	7.4	221	0	HP 6654A	60	9	540
Panel	20	27	6	4	C-28-2	16	96	16	21	1.3	27	0	HP 6038A	60	10	200
ACD +X	**1397**	**1858**									**1858**	**2**				
Circuit 1			4	310	F-28-2	35.2	211	53	256	4.8	1239	1	Agilent N5771A	300	5	1500
Circuit 2			2	310	F-28-2	35.2	211	106	256	2.4	619	1	HP 6035A	500	5	1000
ACD +Z	**1292**	**1718**									**1718**	**2**				
Circuit 1			4	245	H-28-2	52.8	317	79	279	3.5	982	1	HP 6035A	500	5	1000
Circuit 2			3	245	H-28-2	52.8	317	106	279	2.6	736	1	HP 6035A	500	5	1000
ACD -X	886	1178	6	196	H-28-2	52.8	317	53	249	4.7	**1178**	**1**	Agilent N5771A	300	5	1500
ACD +Y	886	1178	6	196	H-28-2	53	317	53	249	4.7	**1178**	**1**	Agilent N5771A	300	5	1500
ACD -Y	886	1178	6	196	H-28-2	53	317	53	249	4.7	**1178**	**1**	Agilent N5771A	300	5	1500
Test Stand																
Circuit 1	TBD												TBD			
Circuit 2	TBD												TBD			

Total	**15,606**	**17**	**18,480**
	11	HP 6035A	11,000
	4	Agilent N5771A	6,000
	1	HP 6654A	1,080
	1	HP 6038A	400

Notes

(1) Margin = 33%

(2) 6 foot strips

(3) all strips in parallel for a circuit

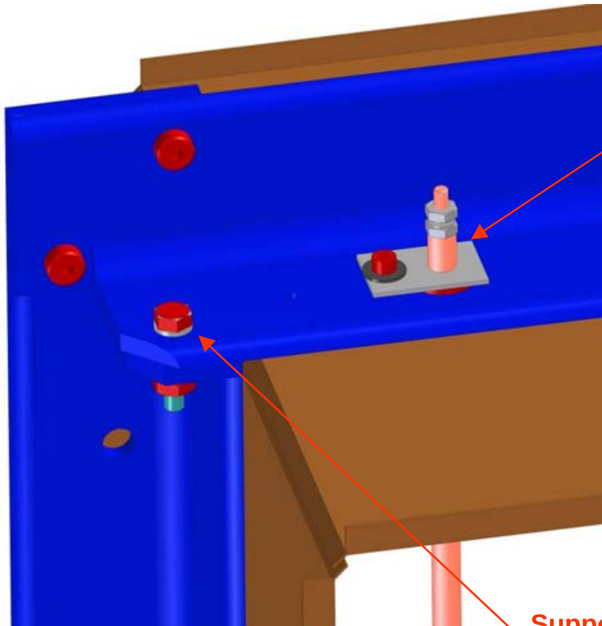
NRL Power Supply Availability and Usage

- Circuits were sized to use the existing supplies available at NRL
  - Each type of supply has at least one spare
- Test Stand will likely require 200-500 watts of additional power using 1-2 supplies
  - This can be accommodated with the spares available

NRL Power Supply Availability and Use						
Model Number	Voltage Range	Current Range	Max Power	Available	Used	Extras
HP 6035A	0 - 500	0 - 5	1000	14	11	3
AT N5771A	0 - 300	0 - 5	1500	6	4	2
HP 6654A	0 - 60	0 - 9	540	2	1	1
HP 6038A	0 - 60	0 - 10	200	3	1	2
HP 6032A	0 - 60	0 - 50	1000	1	0	1

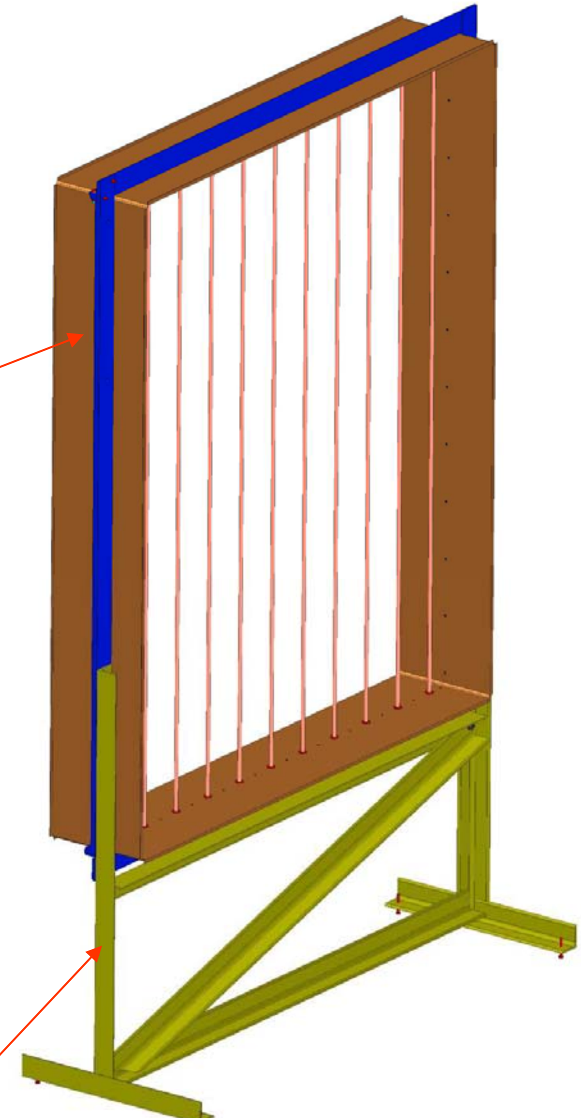
(*) all power supplies are GPIB

Radiator Heater Cage Mechanical Design



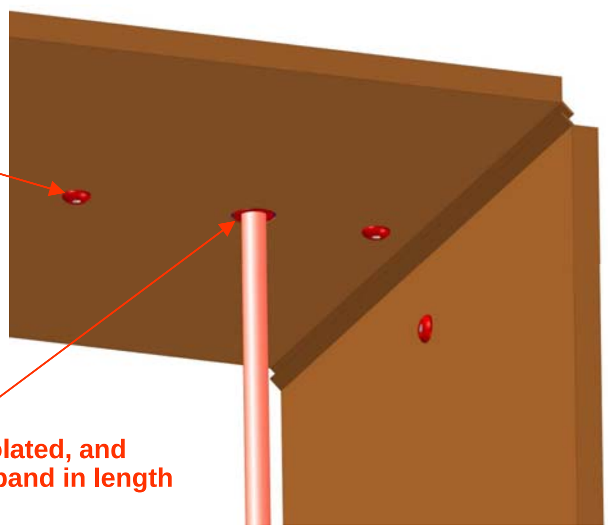
Cal-Rod heaters hang from ceramic spool; flange is part of heater, and screw restrains heater and provides strain-relief for cable

Support has open-sections and bolts together for easy cleaning and set-up



Outer faces of shroud are covered with MLI

Heater cabling will tie off to frame, and route to junction panel on bottom



Polished alum shroud mounts to inside of frame

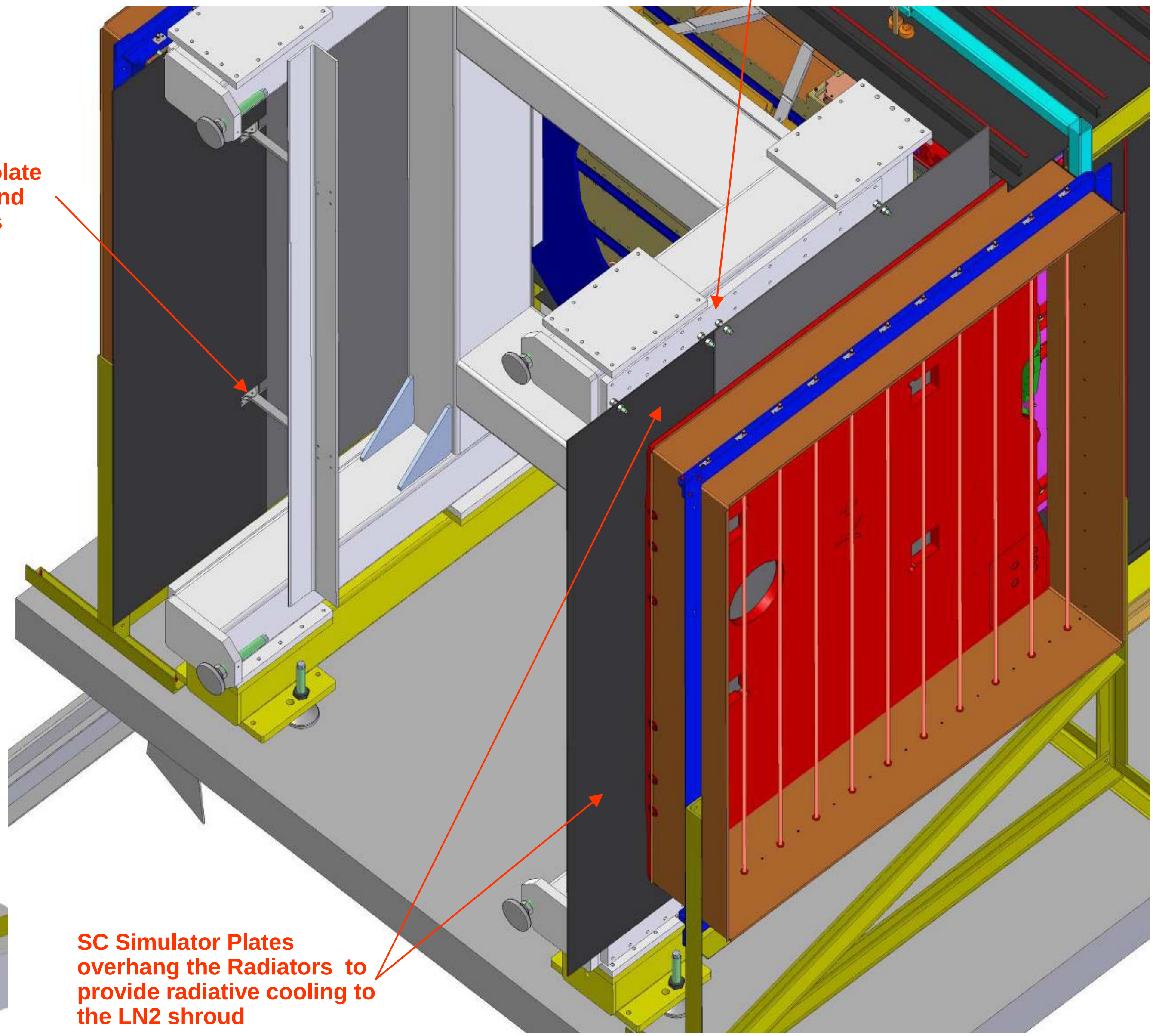
Cal-Rod is thermally isolated, and mechanically free to expand in length

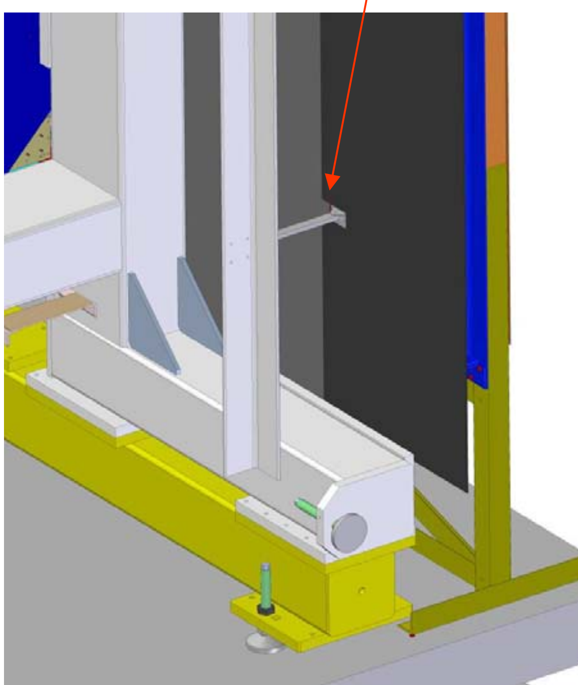
SC Simulator Mechanical Design

SC Simulator Plates hang from mounting posts on leg of Test Stand

Test struts thermally isolate Radiators from Test Stand and SC Simulator Plates

Plates are split so they can be integrated from above, around the Radiator test struts





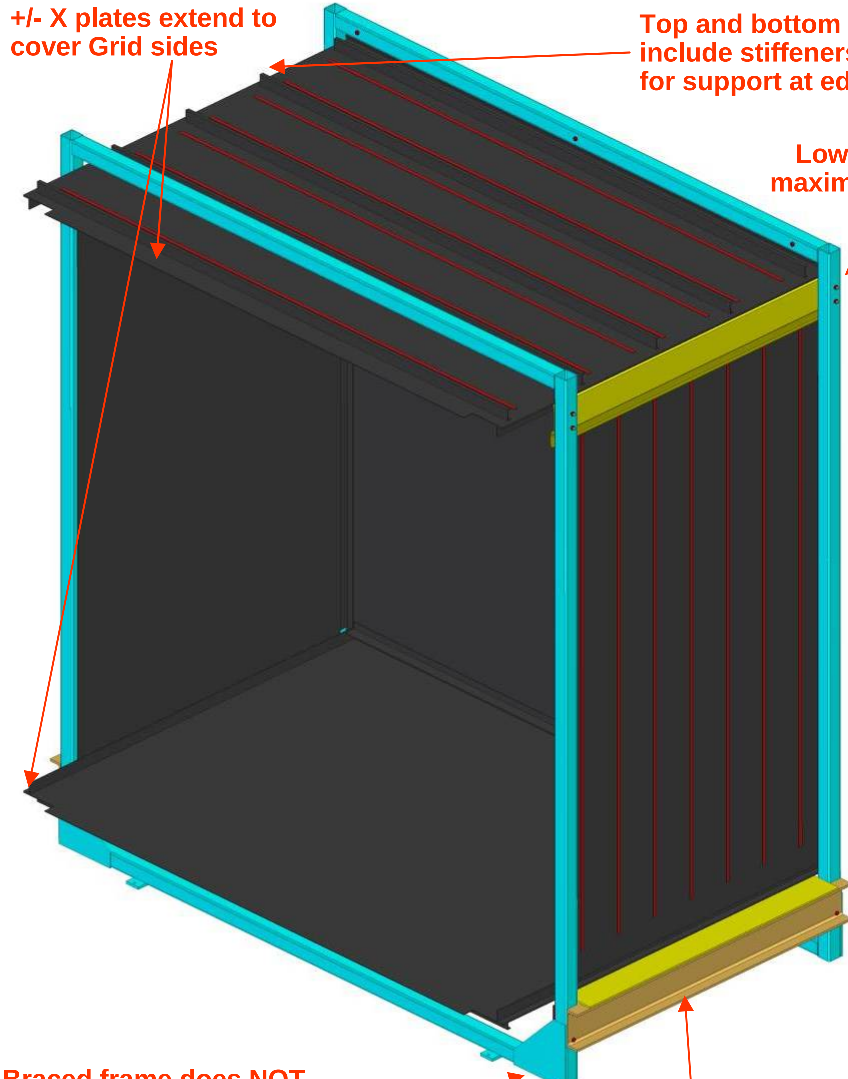
SC Simulator Plates overhang the Radiators to provide radiative cooling to the LN2 shroud

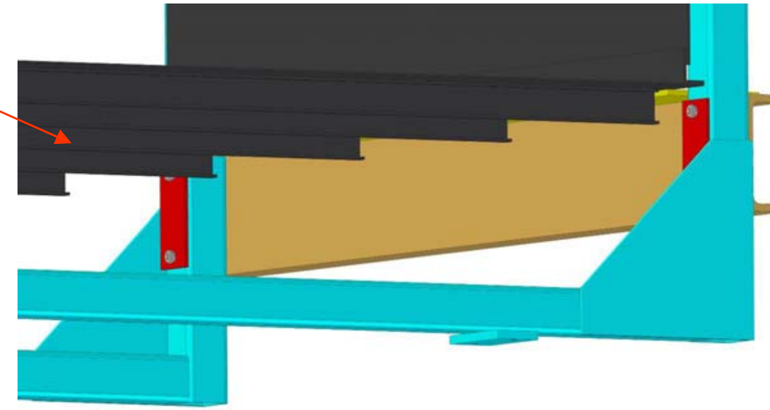
ACD Sink Plate Mechanical Design

+/- X plates extend to cover Grid sides

Top and bottom plates include stiffeners to allow for support at edges only

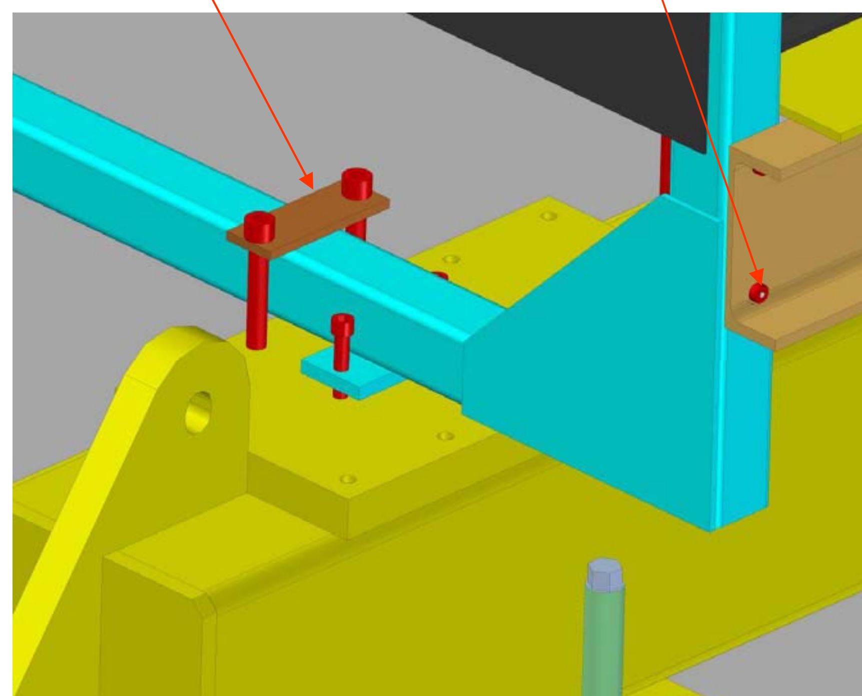
Low profile frame to maximize view factors to shroud





Frame is leveled then dogged down to extension beams

Bolt-together frame pieces allows for assembly around ACD

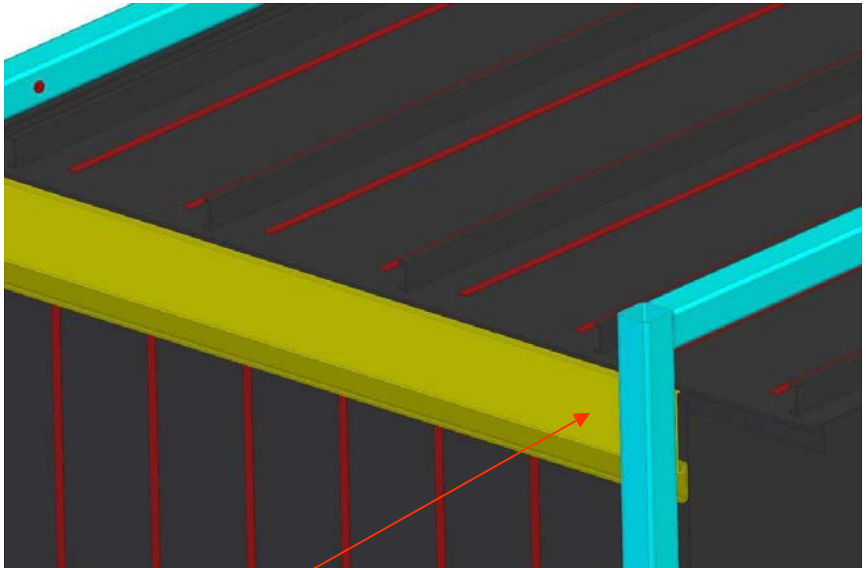


Braced frame does NOT rely on sink plates for shear strength—allowing plates freedom to expand/contract

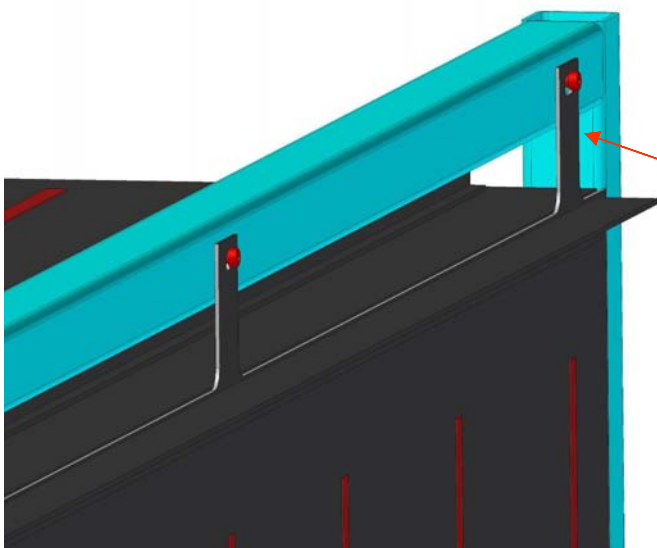
ACD Sink Plate frame is free-standing

>sits on Test Stand extensions
>easily adaptable for Obs T-Vac test

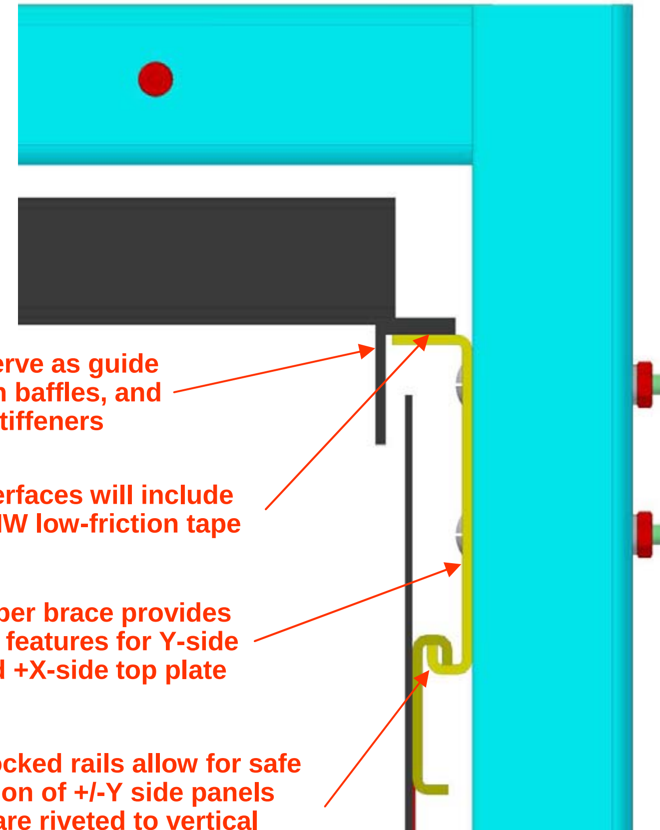
ACD Sink Plate Mechanical Design (cont.)



Bolt-on frame bracing double as rails for inserting sink plates



+Z Plate hangs from end frame



End angles serve as guide rails, radiation baffles, and longitudinal stiffeners

Sliding interfaces will include teflon/UHMW low-friction tape

Upper brace provides rail features for Y-side and +X-side top plate

Interlocked rails allow for safe insertion of +/-Y side panels (rails are riveted to vertical panels)

STE Validation Test Plans

- **Radiator Heater Cage**
  - **Purpose**
    - Validate that cal-rods produce a uniform equivalent sink temperature distribution
    - Verify that cal rods can follow the transient profile required to simulate the on-orbit transients
    - Bake out both sets of cal-rods to their max expected temperature
  - **Test**
    - Bake-out is required for both Heater Cages, and could be done during the overall STE/MGSE bake-out cycle
    - Validation testing is done using only one Heater Cage, and the second cage is used just as a support since it does not need to be removed
  - **Additional STE**
    - Add a plate to simulate the heat load from the Radiators
    - Use one plate between the two Heater Cages with 600 W of heaters on it
    - Put MLI on one side of the plate
- **SC Simulator and ACD Sink Plates**
  - **Purpose**
    - Validate that the predicted powers for the SC Simulator and ACD Sink Plates are adequate to balance the radiative losses to the chamber cold shroud
  - **Test**
    - Run SC Simulator at its max predicted temperature and verify that heaters are running at <100% duty cycle
    - Instrument the plates to verify that they are suitably isothermal
  - **Additional STE**
    - Add MLI blankets to the LAT-side of the plates—this produces a conservative boundary condition, since the LAT would otherwise be radiating some process heat to the panels

Thermal-Vacuum Test Planning

- Summary
  - The thermal, electrical, and mechanical design of the LAT thermal-vacuum test has been completed
  - The test STE design is responsive to the requirements laid out in the T-Vac Test Plan
  - All STE hardware shown has been designed and detailed drawings are in the works
  - Existing NRL power supplies have been identified, including spare
  - Validation test plans have been developed
- Next Step
  - Complete STE drawings—expect drawing release by late September
  - Develop hardware list for EGSE
    - Work up details of cable routing and connections, inside and outside the chamber
    - Identify any personnel or other hazards associated with heater circuits
    - Locate/buy cabling, additional TC’s, panels, etc.
  - Write validation test procedure
    - Includes more detailed schematic of electrical set-up
  - Develop comparable detail for test operations
    - Identify test scripts and functionality for running Validation and LAT T-Vac tests
    - Finalize test data requirements and presentation/storage formats